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SPACE CONSTRUCTION SYSTEM ANALYSIS

PART 2 FINAL REPORT
CONSTRUCTION ANALYSIS
APRIL 1980

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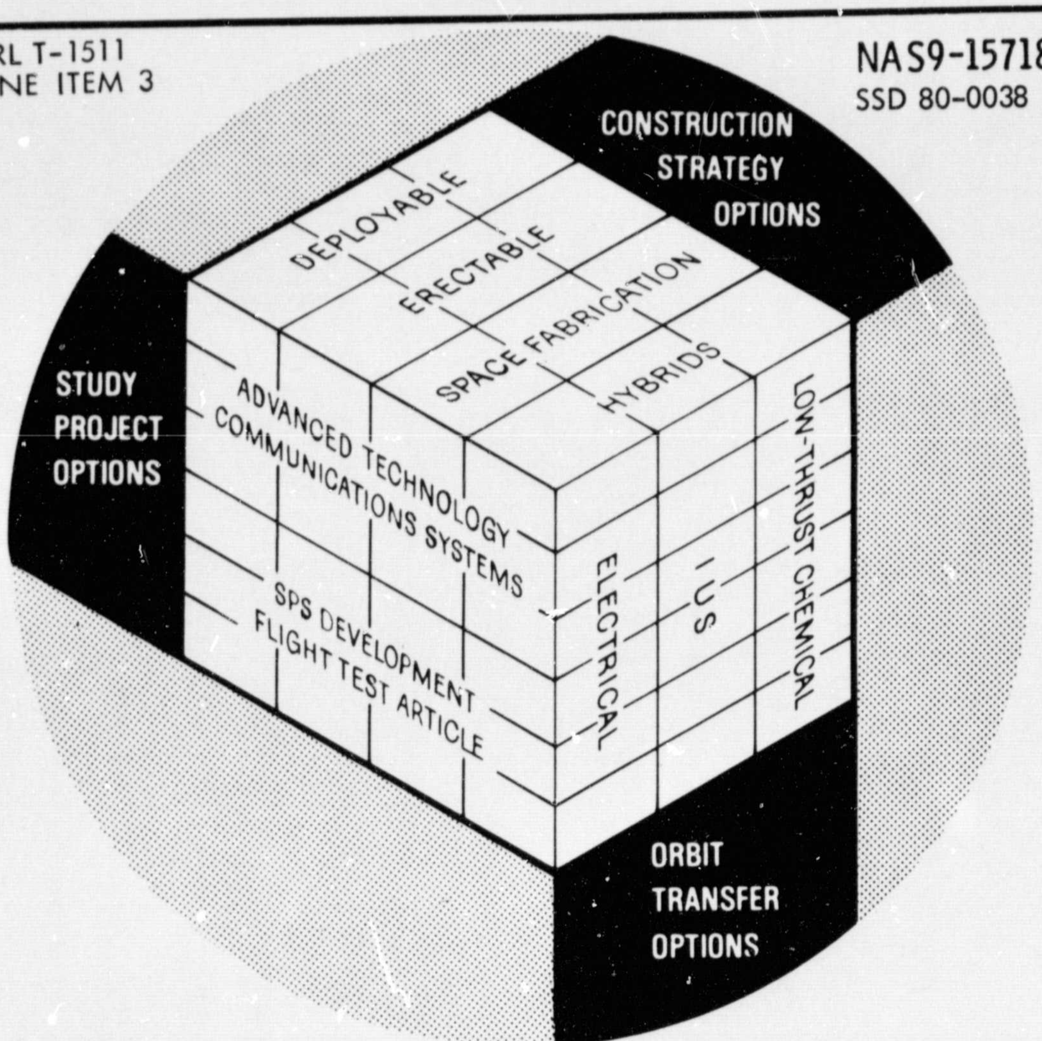

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SPACE CONSTRUCTION SYSTEM ANALYSIS
PART 2, FINAL REPORT

Construction Analysis

APRIL 1980

NAS9-15718

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Satellite Systems Division
Space Systems Group

Rockwell International

FOREWORD

This report summarizes the construction analysis procedures and results for the Engineering Technology Verification Platform (ETVP). The ETVP was selected at the end of Part I of the study for use as a model system to study space construction concepts and processes. The construction requirements, platform design definition, and related rationale in this analysis are the study products from Task 8 of Contract NAS9-15718, Space Construction System Analysis Study. This contract effort was conducted by the Space Operations and Satellite Systems Division, Space Systems Group of Rockwell International Corporation for the National Aeronautics and Space Administration, Johnson Space Center. The work was administered under the technical direction of the Contracting Officer's Representative (COR), Mr. Sam Nassiff, Spacecraft Systems Office, Spacecraft Design Division, Johnson Space Center.

The study was performed under the direction of Ellis Katz, Study Manager. The following persons made significant contributions toward completion of the analyses reported herein.

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Major documents resulting from Part II of the contract effort are listed below:

Space Construction System Analysis, Part 2, Platform Definition, Final Report SSD 80-0037

Space Construction System Analysis, Part 2, Construction Analysis, Final Report SSD 80-0038

Space Construction System Analysis, Part 2, Cost and Programmatics, Final Report SSD 80-0039

Space Construction System Analysis, Final Report, Space Construction Experiments Concepts SSD 80-0040

Space Construction System Analysis, Part 2, Executive Summary, Final Report SSD 80-0041

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ILLUSTRATIONS

ILLUSTRATIONS
(Continued)

TABLES

1.0 INTRODUCTION

This report presents the system analyses of space construction which were performed as Task 8 of Part 2 of the contract study, Space Construction System Analysis (Contract NAS9-15718). Closely associated with this task effort is the design effort to define a model project called the Engineering and Technology Verification Platform (ETVP). The design studies and definition of this platform described in a separate companion report, which will be referenced herein where appropriate (Reference 1-1).

1.1 PURPOSE AND SCOPE

This report describes the construction methods and results specific to the end-to-end construction process derived for building the ETVP in low earth orbit, using the Space Shuttle Orbiter as a construction base. The majority of analyses concern three missions required to build the basic platform. However, consideration is also given to later orbiter missions which will update and revise payloads in low earth orbit and will install propulsion units for transfer of the platform to geosynchronous orbit under its own guidance. Provisions are also included for servicing and changeout of payloads in geosynchronous orbit using a teleoperator vehicle. However, details of such operations are not developed herein. Design features of the platform are discussed only in regard to construction requirements.

1.2 STUDY METHOD

The system analysis study approach was based on postulating a design concept for a specific construction project (the ETVP), then developing a logical plan for performing the construction within realistic constraints and cost minimization considerations. As the study proceeded, selected design changes and detail definitions of hardware concepts were developed to accommodate or facilitate specific construction processes and/or equipment. This iterative study process, which has been previously described in Rockwell reports (Reference 1-2), is illustrated in Figure 1.2-1. The detail design and construction analysis process proceeded in chronological sequence, mission by mission, from initiation of construction through checkout, with foreknowledge of expected needs and techniques from previous studies in Part 1 of this study contract (References 1-2 through 1-6). Selected major construction steps were analyzed and documented as separate activities including power, time and crew requirements. These data packages, described later in Section 5.3, formed a core of information for an end-to-end integration of each mission, incorporating additional requirements for lighting, television, power, crew rest and ingress-egress periods. The results of these analyses were summarized in terms of integrated timelines, power profiles, energy requirements and construction equipment needs.

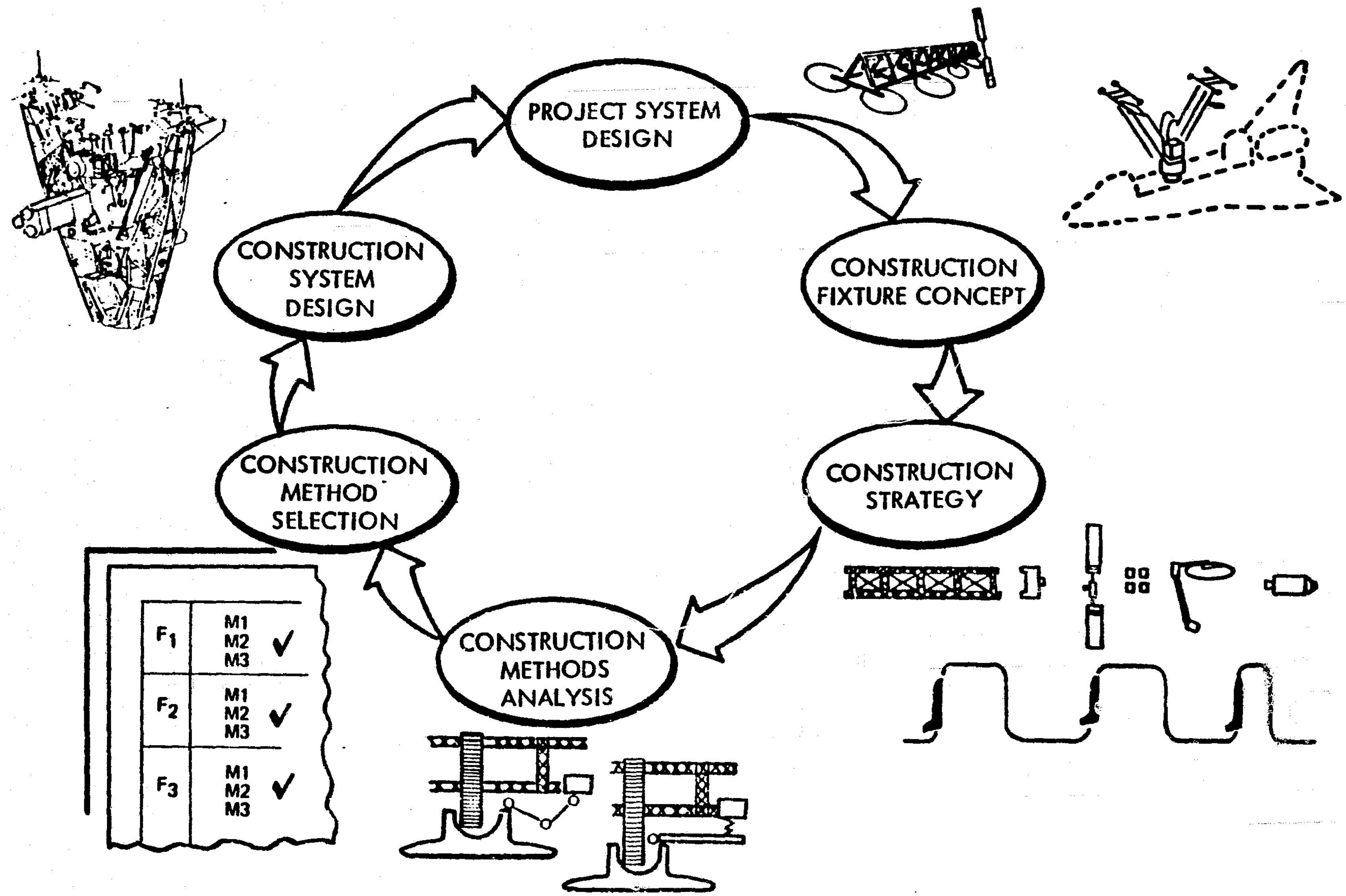


Figure 1.2-1. Iterative Construction Process

In parallel with the analyses of on-orbit construction, trajectory analyses were conducted to determine time from launch to beginning of construction, on-orbit delays for entry opportunities and the descent/landing time. Such data formed the basis for overall mission consumables requirements, total launch weight estimates and relative costs. Details of these analyses are described later.

1.3 ORGANIZATION OF CONTENTS

The book is organized with the general philosophy of first presenting requirements, then analyses, then a summary of results. Section 2.0 provides overall, general construction requirements and those related to the platform design concept. Section 3.0 presents the general strategy selected for construction. Section 4.0 provides specific guidelines and assumptions, divided according to mission phases, and functions of the orbiter, crew and construction equipment. Sections 5.0 through 7.0 describe the analyses for each of the construction missions. The content of these sections has a common format, describing the overall construction plan, individual construction processes, integration analyses and the cargo manifest.

A composite summary of the overall construction project activity including the construction system/equipment definition, corresponding resource requirements, orbiter mods and platform servicing operations related to the construction system design is presented in Section 8.0. Section 9.0 summarizes the conclusions and recommendations.

Three appendixes are provided. The first (Appendix A) contains copies of design drawings which are specific to construction equipment and techniques. Appendix B contains copies of all the Construction Activity Data Sheets which provide details on what is done, sketches of hardware concepts, and estimates of time, power and energy for key equipment items. Also noted therein is an indication of crew workload. Appendix C presents the detail mass properties summary tables for each of the three construction missions.

References are listed as appropriate at the end of each major section (e.g., 1.0, 2.0, 3.0, etc.), and are numbered in a separate sequence for each section.

1.4 REFERENCES

1-1 Space Construction System Analysis, Part 2 report, Platform Definition, SSD 80-0037, Rockwell International, March 1980

1-2 Space Construction System Analysis, Project Systems and Mission Descriptions, Task 1 Final Report, SSD 79-0077. Rockwell International, Satellite Systems Division, 26 April 1979

1-3 Space Construction System Analysis, Task 2 Final Report, System Analysis of Space Construction, SSD 79-0123, Rockwell International, Satellite Systems Division, June 1979

1-4 Space Construction System Analysis, Task 3 Final Report, Construction System Shuttle Integration, SSD 79-0124, Rockwell International, Satellite Systems Division, June 1979

1-5 Space Construction Data Base, SSD 79-0125, Rockwell International, Satellite Systems Division, June 1979

1-6 Space Construction System Analysis, Special Emphasis Studies, Final Report, SSD 79-0126, Rockwell International, Satellite Systems Division, June 1979

2.0 CONSTRUCTION REQUIREMENTS

Specific construction requirements were established for both the platform configuration and for the construction activities. These requirements are discussed in the following sections.

2.1 PLATFORM CONFIGURATION REQUIREMENTS

From the previous Part I analysis, a linear platform configuration was determined to be the easiest configuration to construct and was structurally adequate to perform as a communications platform. Consequently, a linear platform was utilized as the model for the construction analysis.

The primary structure was required to be assembled from beams fabricated by the automatic beam fabrication device—beam builder—being developed by the General Dynamics Corporation. The structure would utilize lap joints, rather than butt joints, to simplify the construction process. The material thickness would be defined by a structural analysis, and variations from the basic GD beam fabricated from the beam builder would be coordinated with GD to verify the feasibility of producing the required beam size.

The crossbeams of the platform will be located in a common plane rather than being staggered. This requirement is imposed because it reduces the size of the construction fixture, reduces the time of construction, and minimizes the complexity of installing the diagonal cord members.

The platform was sized to accommodate communications antennas up to 20 m in diameter. The platform configuration must also be sized to be within the reach envelope of the orbiter RMS. The combination of these requirements was instrumental in determining the length of the long crossbeams to which the payloads are mounted and also the distance between crossbeams - bay spacing.

All of the electrical lines distributing power to the payload attach ports, RMS modules, and orbit transfer propulsion modules interface will be run along only one of the longitudinal members. Data distribution lines will also be run along the same member with sufficient spacing to prevent EMI interference. This will concentrate the wire laying activity in one location, thus minimizing the installation effort and equipment required to perform this function.

A system control module (SCM) was required to house all of the systems necessary to operate the platform. This module will include the solar array power generation, the power regulation and distribution electronics, and the power storage battery system. GN&C controls, sensors, and CMG's would also be included as well as the TT&C system. This requirement concentrates all of the systems into a single module that can be installed as an integral unit. This requirement also provides a single location for servicing and maintenance of the

equipment. All of the systems would be packaged into LRU modules. These modules would be configured for removal and replacement by the orbiter RMS in LEO and by remote or manned servicing vehicles in GEO.

In addition to platform systems servicing provisions are also required for LEO and GEO servicing of the payloads. LEO servicing will be accomplished via the orbiter RMS and cherry picker while berthed to the construction fixture. GEO servicing provisions must be compatible with both remote and manned concepts.

Implementation of these requirements resulted in the platform configuration described in detail in the Engineering Test and Verification Platform Definition (Section 3.0 of Reference 2-1).

2.2 CONSTSUCTION ACTIVITY REQUIREMENTS

The construction activity requirements considered both the construction system/equipment design and the construction/assembly processes. The principal activity requirements are as follows.

The platform shall be constructed from the orbiter as the construction facility. The orbiter shall provide all of the power and construction control and software necessary to perform the construction/assembly, and checkout operations.

All of the construction activities shall be performed in the immediate vicinity of the orbiter. This requirement permits the concentration of the construction equipment in one general location and allows the utilization of the orbiter facilities to support the operations. The opportunity to have direct visibility of the construction activities is also available.

The construction operations consider the utilization of the construction support equipment that is currently being developed and will be available in the late 1980's - the estimated period for construction. This includes such items as the beam builder, the manned remote work station (cherry picker), the manned maneuvering unit (MMU), and the RMS. As the construction analysis developes, recommended modifications to these items will be defined.

During construction a free-drift mode shall be utilized. Consequently, the orbiter will not be required to maintain a prescribed orientation; thus simplifying the orbiter operations and minimizing the utilization of expendables. Studies from Part I have verified the feasibility of performing construction in this mode.

The construction operations shall be arranged to minimize the time of construction. This requirement will reduce the time on orbit with the associated reduction of electrical energy, crew expendables and mission costs.

EVA shall be considered for those activities where increased construction effectiveness and/or construction system simplicities can be expected.

Where feasible, the direct visibility of the construction activities is desirable, rather than observing the activity via CCTV.

Between flights, contact with the project shall be maintained. The capability to stabilize the project for revisit berthing is required. The project must be stabilized within a residual rate of approximately 0.01-0.02 deg/sec. This rate permits the capture of the platform with the orbiter RMS.

Safety of the crew and of the orbiter shall be considered when deriving the construction activities.

The implementation of these requirements is reflected in the construction strategy (Section 3.0), and in the three construction missions (Sections 5.0, 6.0, and 7.0) of this report.

2.3 REFERENCES

2-1 Space Construction System Analysis, Part 2, Platform Definition, Final Report No. SSD 80-0037, Satellite Systems Division, Rockwell International, March 1980

3.0 CONSTRUCTION STRATEGY

The construction strategy for the ETVP was evolved from previous analyses during Part I of this study. The major construction strategy issues identified and the decisions which were made for the ETVP analysis concerning these issues are presented in this section. In general, it was found that construction strategy is inseparable from the design of the platform and the construction equipment as well as the mission operations scenario and the space environment. Also, the economics and logistics of Shuttle operations are major drivers in selecting construction strategy. The importance of these interactions is apparent in the following discussion.

3.1 CONSTRUCTION FIXTURE SYSTEMS AND WORK PLACE GEOMETRY FACTORS

The principal concepts for space construction fixture systems were derived from earlier analyses of a space-fabricated communications platform design; they are listed and discussed below.

1. To the degree feasible, the platform will be constructed using the Space Shuttle orbiter as the major base of on-orbit operations (as compared to a separate, manned, on-orbit facility). This "going-in" decision was based upon the magnitude of the construction effort, size of the platform, and evaluational nature of the platform as a construction project and as a communications equipment platform. As will be brought out during the discussion of analyses, some base support functions were necessary for a construction fixture, which is left on orbit between orbiter visits.

2. The construction is to be performed during free-drift conditions, rather than using a stabilized platform concept. This decision was based on considerations of potential stress loads and equipment requirements for handling large objects during periods when thrusting would be required for stabilization, considerations of costs and complexity of control systems, weight, and volume requirements for RCS fuel during construction.

3. A compact work area is desirable in order to limit travel time of the principal construction equipment and EVA personnel, and to minimize power requirements for lighting. This led to the general concept of "bringing the work to the work place" (as in a factory assembly line) by mechanically moving the platform through a compact construction fixture.

   The physical embodiment of this concept was envisioned as a primary construction fixture having multiple functions, as illustrated in Figure 3.1-1. Details of the various functions and the overall construction fixture deployment and operation are presented in later mission analyses discussions.

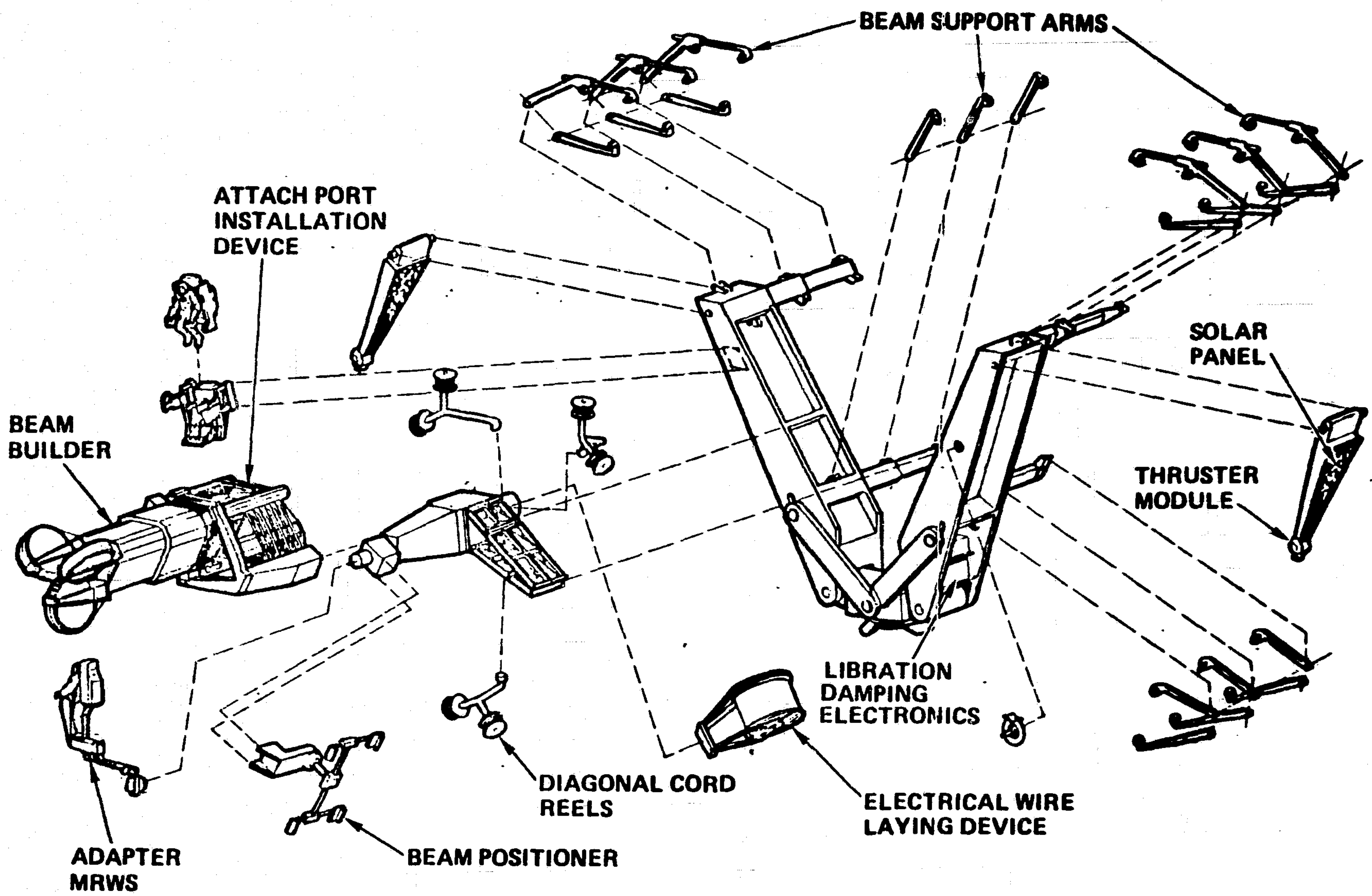


Figure 3.1-1. Station 1 Construction Fixture and Equipment

4. The benefits of automation available in automatic beam builder machines should be employed where feasible. Platform designs featuring long, uninterrupted beam spans take advantage of this capability and are compatible with Item 3.

5. Efforts to reduce mission time on orbit are likely to be cost effective since they minimize the amount of boiloff of cryogenic fuel, minimize the need for stowage volume and weight for crew supplies and breathing gas, minimize fuel for orbiter systems maintenance, and generally minimize daily on-orbit costs. As regards construction equipment, the basic strategy concept resulting was that automation and parallel operations should be used, where appropriate, to minimize construction time.

   This concept is reflected in the developed construction system by utilization of two major construction stations, as illustrated in Figure 3.1-2. Transverse beam subassemblies are fabricated at Station No. 2; they are then transported to, and assembled, at Station No. 1 while additional transverse beams are being fabricated.

3.2 GENERAL CONSTRUCTION SEQUENCE GUIDELINES

The following general guidelines apply to setting up an effective construction sequence:

1. Set up construction fixture early in the project (probably first activity).

2. Construct basic structure prior to attaching subsystem modules and flexible items such as electrical power and signal lines. Note that paralleling electrical power and signal lines can be installed as a beam is fabricated and/or installed.

3. Consider thermal constraints on flexible plastic wire coverings, and other materials which might be brittle at low temperatures. Schedule for deployment during periods of solar heating when required (or provide thermal conditioning).

4. Install nickel-hydrogen batteries toward end of construction project, provide for thermal conditioning (radiator) at time of installation, and put them on line as soon as possible to avoid extended periods of storage in charged condition.

5. Deploy large area solar arrays as late as possible to avoid destabilizing influence of drag forces.

6. Install orbit transfer modules as the last installation to minimize boiloff of cryogenic propellants.

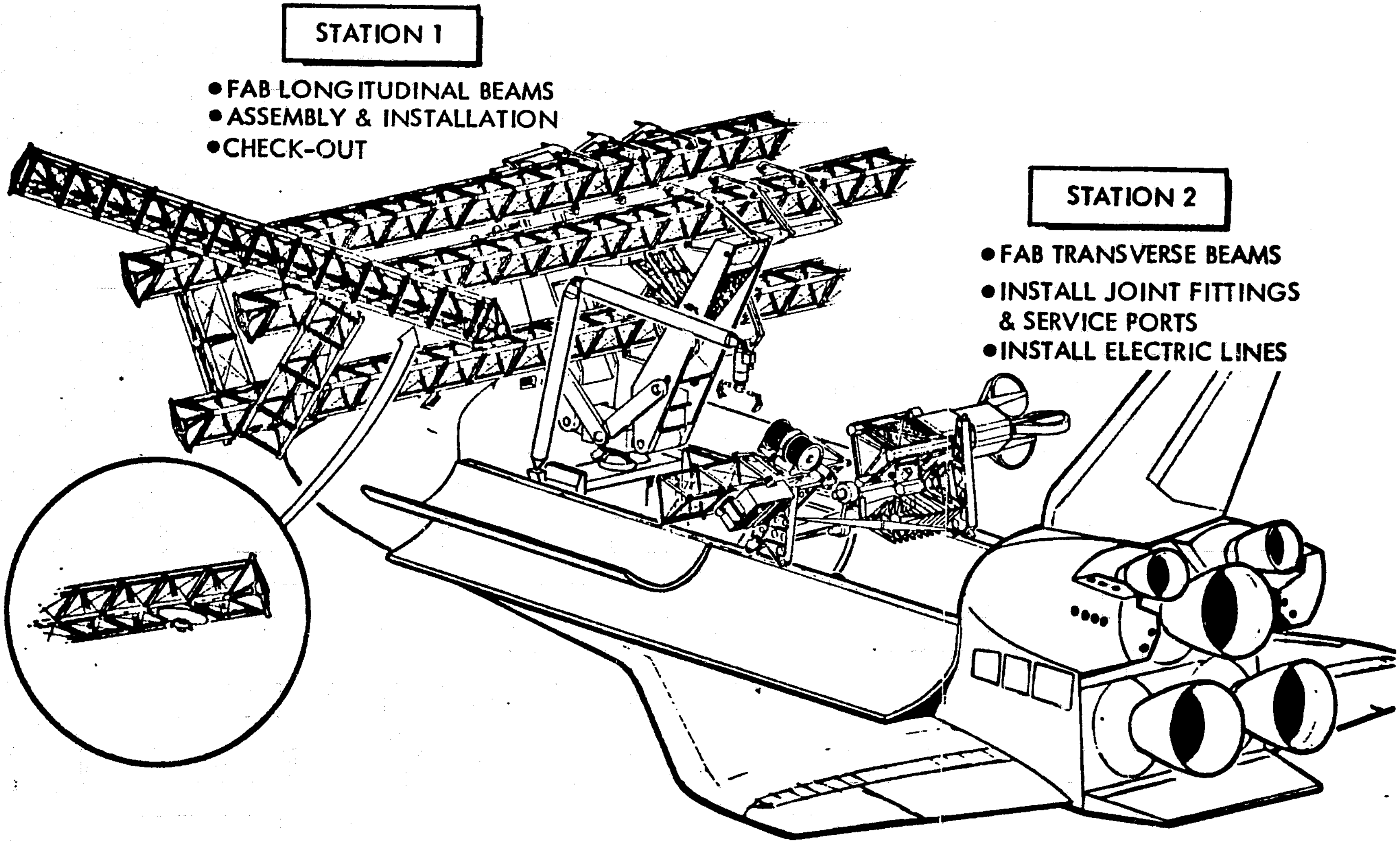


Figure 3.1-2. Construction Fixture Systems

7. It is desirable to manufacture all three longitudinal beams first to avoid the necessity of storing transverse beams and crossbeams and/or using two beam machines simultaneously.

3.3 OPERATIONS AND LOGISTICS CONSIDERATIONS

The overall construction strategy includes considerations of cost-effective use of orbiter and crew time on orbit, weight and volume carrying capacity, and constraints on power and total energy resources. The following general concepts were applied.

1. Minimizing time on orbit minimizes daily costs of orbiter operations and effectively utilizes the orbiter energy resources and cryogenic supplies. In general, crew utilization for construction is enhanced by multiple-shift operations. Therefore, the general strategy employed was to attempt to provide a maximum number of crew shifts per day with a minimum size crew, so as to supervise and monitor automated equipment and thus continue construction, maximizing machine time and serial EVA crew time each day.

2. To avoid weight and cost of storage racks on construction fixtures or other on-orbit facilities, the orbiter bay packaging should be selected to include only that equipment and material which can be utilized for construction during the given Shuttle flight.

Thus, the early missions must carry up the basic construction fixtures and structure fabrication materials, while later missions include equipment modules installed on the structure, checkout equipment, and payloads.

3.4 DESIGN-RELATED CONSIDERATIONS

An important consideration in planning the strategy for construction involves the detail design features of the platform itself which affect construction equipment design, assembly processes, power demand, and total energy. Table 3.1-1 lists several key design concepts which affect and interact with construction processes, and briefly summarizes the construction implications.

Table 3.1-1. Construction Implications of Design Features

FEATURE	CONSTRUCTION IMPLICATIONS
BERTHING PORT DEVICES FOR INSTALLATION OF MAJOR SYSTEMS MODULES & COMPONENTS.	• REQUIRES LOAD-SPREADING INTERFACE STRUCTURE BETWEEN BERTHING PORT RING AND BASIC STRUCTURE. ADDITIONAL STOWAGE AND ASSEMBLY FUNCTIONS REQUIRED FOR EACH PORT. • PROVIDES POSSIBILITY OF SOFT BERTHING FLY-IN INSTALLATION BY REMOTELY CONTROLLED VEHICLE OR DIRECT ATTACH BY RMS, CHERRY PICKER, OR OTHER MECHANISM. • PROVIDES MEASURE OF SELF-ALIGNMENT. INSTALLATION DEVICE MUST GIVE WAY/YIELD TO ACCEPT THIS FEATURE. • MODULES MAY BE INSTALLED DURING STRUCTURE ASSEMBLY OR LATER AS DESIRED OR APPROPRIATE.
ANTENNAS DESIGNED FOR SINGLE-POINT ATTACH TO BASIC STRUCTURE (BERTHING PORT), POWER, SIGNAL, ETC., CONNECTIONS INTEGRATED WITH ATTACHMENT. (SEPARATE FUNCTIONS WHICH OCCUR SHORTLY AFTER MECHANICAL ATTACHMENT).	• ANTENNAS HANDLED AS SINGLE MODULES FROM LOADING INTO ORBITER THROUGH INSTALLATION TO SPACECRAFT STRUCTURE. • CONSIDERATIONS OF INSTALLING LARGE MODULES APPLY. • DEPLOYMENT FOLLOWS INSTALLATION TO BASIC STRUCTURE. • CONCEPT IS ESSENTIAL FOR SUCCESS IN GEOSYNCHRONOUS, REMOTELY CONTROLLED INSTALLATION.
RCS UNITS DESIGNED FOR SINGLE-POINT ATTACH TO BASIC STRUCTURE.	• RCS UNITS HANDLED AS SINGLE MODULES. • CONSIDERATIONS OF INSTALLING LARGE MODULE APPLY.
BEAMS FORMED OF SPACE-FABRICATED MATERIAL BY AUTOMATIC MACHINE	• REQUIRES DEVICES TO HOLD AND POSITION MACHINE AND BEAMS, TRANSLATE AND TRANSPORT BEAMS AND BEAM BUILDER MACHINE. • PROVIDES POSSIBILITY OF CONTROLLING CONFIGURATION BY SOFTWARE INPUTS TO BEAM BUILDER MACHINE. • FAVORS AUTOMATIC INSTALLATION OF END FITTINGS, JOINT FITTINGS, WIRES, AND SPECIAL REINFORCEMENT FEATURES. • REQUIRES MEANS TO JOIN BEAMS TO FORM STRUCTURES.
LONG, NARROW TRUSS WORK STRUCTURE CONFIGURATION OF PLATFORM	• FAVORS UNINTERRUPTED LONGITUDINAL BEAM FABRICATION. • REQUIRES MEANS TO TRANSLATE STRUCTURE WITH RESPECT TO CONSTRUCTION FIXTURE.
MULTIPLE ELECTRICAL CABLE CONNECTIONS, CROSS-BRACE CORD INSTALLATION AND TENSIONING	• FAVORS DIRECT MANUAL OPERATION (EXTRAVEHICULAR ACTIVITY).

4.0 GUIDELINES AND ASSUMPTIONS

This section describes guidelines and assumptions significant to the planning and end-to-end analyses of the construction operations and equipment.

4.1 PRELAUNCH, ASCENT, RENDEZVOUS, BERTHING, DEORBIT, AND ENTRY FUNCTIONS

Prelaunch and ascent functions significantly affect how much and in what way construction equipment and materials are carried aboard the orbiter, their accessibility for construction, and their deployment requirements. Also affected are crew activity timelines and planning for consumables. Therefore, considerations of guidelines and assumptions relative to these functions, as accomplished with the orbiter, is pertinent to the overall system analysis of space construction. Similar considerations apply also to deorbit and entry functions which are also discussed here.

4.1.1 Payload Bay Packaging

Table 4.1-1 lists pertinent guidelines and assumptions relative to cargo bay packaging for space construction.

Table 4.1-1. Guidelines and Assumptions for Payload Bay Packaging

- Cargo center-of-mass locations must be compatible with requirements of Volume XIV (Reference 4-1).
- EVA access space in the forward portion of the payload bay may be obstructed by stowed cargo items if emergency provisions are included for remotely controlled jettisoning or removal of such obstructions.
- Provisions must be incorporated to permit rendezvous with the construction fixture and berthing of the primary construction fixture to the orbiter's berthing facility.
- Emergency provisions for jettisoning must be included for any deployable modules or equipment which could obstruct closing of payload bay doors by failure to be stowed or retracted.
- Packaging should be designed to permit ready access to equipment and materials as needed for construction.
- Packaging shall permit stowage of return cargo so as to be compatible with c.g. location limits per Volume XIV (Reference 4-1).

4.1.2 Flight Performance

Ascent and descent trajectory data are presented in order to establish complete mission profiles for the end-to-end construction analysis. These are representative data based on current preliminary orbiter operating rules and procedures. In some cases judgemental logic was applied to select typical values for parameters which could vary over a range of high and low extremes, e.g., ascent phasing, pre-entry thermal conditioning, etc.

Typical ascent trajectory data characteristics are illustrated in Figure 4.1-1. It is noted that the load factor is limited to 3 g by means of orbiter engine throttling.

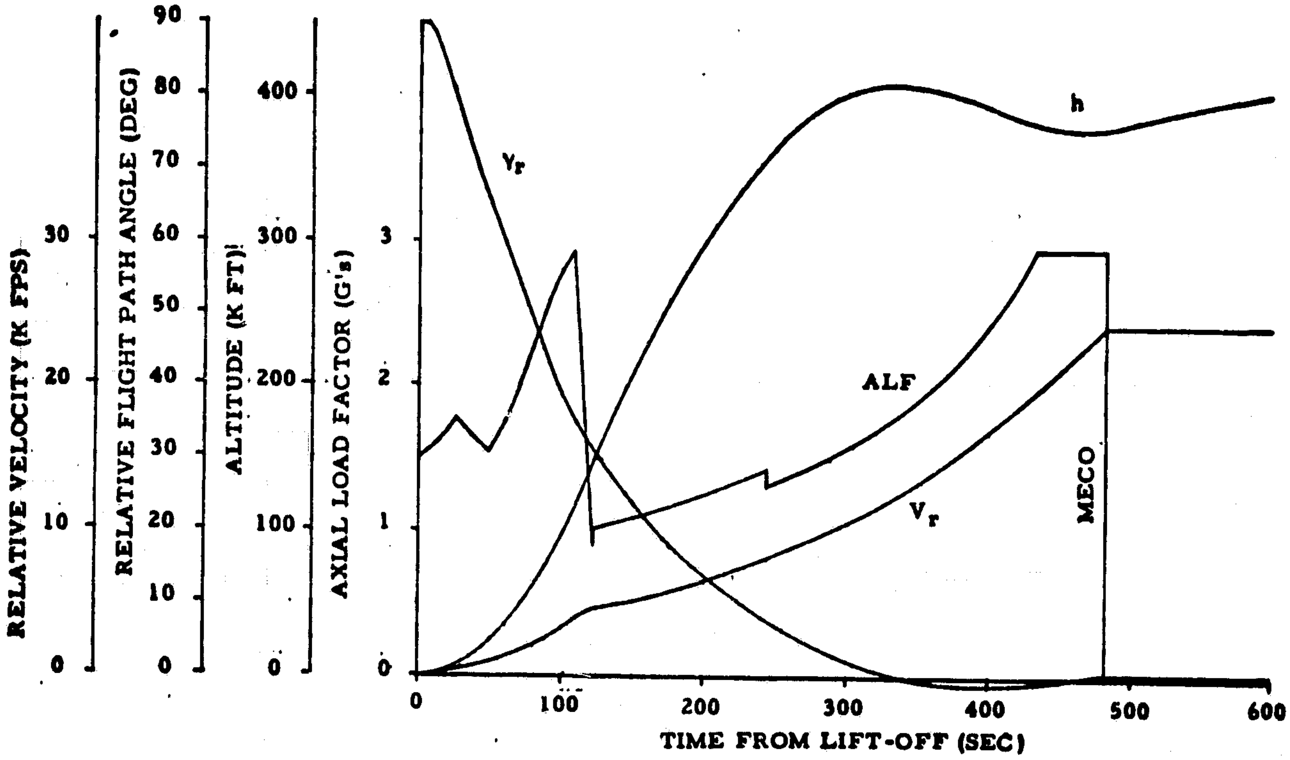


Figure 4.1-1. Typical Mission Ascent Trajectory Data

For all except the first mission, the ascent profile will be that in which the orbiter must rendezvous and berth with the construction fixture/ platform assembly. The timeline development for this type of mission is considered first.

The Space Shuttle trajectory is optimized for *intact abort* capability. This provides an abort-once-around (AOA) capability at the time the return-to-launch-site (RTLS) capability is lost.

As part of the nominal mission profile mission, the orbiter is always initially injected into a 93×182-km elliptical orbit. At the apogee of this orbit, an OMS circularization burn is performed to place the orbiter in a more stable 182-km circular orbit. Any necessary phasing and orbiter checkout with ground stations are performed at this altitude.

The phasing requirements depend on mission geometry at launch and on the target orbit altitude. This relationship is illustrated in Figure 4.1-2 for the worse-case geometry. However, it is felt that considerably shorter phasing periods will actually be required as launch time will be completely arbitrary. It is assumed that 50% of the maximum phasing time is more than adequate for construction mission planning purposes.

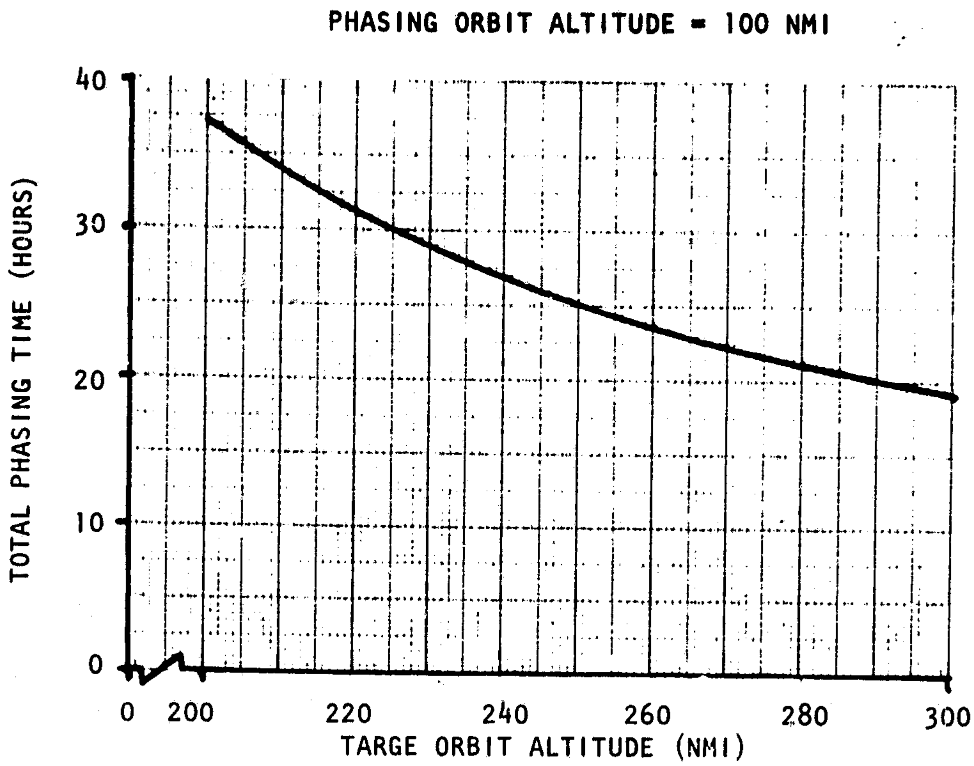


Figure 4.1-2. Total Maximum Phasing Time

After completion of necessary phasing and/or checkout of the orbiter, a go-ahead is given to proceed to the mission altitude. This ascent scenario does not preclude missions where direct ascent-to-mission altitude is performed without going through the intermediate 182-km circular parking orbit. Such missions obviously shorten the time from liftoff to insertion in the mission orbit, but affect the mission planning analysis only in a superficial manner.

Reference Ascent Profile

A typical profile timeline for a rendezvous mission with an arbitrary 12-hour phasing is presented in Table 4.1-2.

A detailed description of the activity in each phase follows.

Table 4.1-2. Mission Ascent Timeline
(Rendezvous with 12-hr Phasing)

MISSION PHASE SUBPHASE EVENT/OPERATION	MISSION G.E.T.	DURATION	REMARKS & COMMENTS
● POWERED ASCENT			
MATED ASCENT			
LIFTOFF	00 00 00	00 00 00	
CLEAR LAUNCH TOWER	00 00 05	00 00 00	LAUNCH TOWER IS ASSUMED TO BE IN HEIGHT
PERFORM PITCH PROGRAM (TRAJ. SHAPING)	00 00 05	00 00 10	
MAXIMUM DYNAMIC PRESSURE	00 00 54	00 00 00	
WATER BOILER ACTIVATION	00 01 45	00 00 00	30 km ALTITUDE-UP TO THIS POINT NO ACTIVE COOLANT LOOP
SRB TAILOFF	00 01 53	00 00 05	
SRB-ORBITER/ET SEPARATION			
BEGIN ORBITER TVC	00 02 00	00 00 00	
INITIATE SRB STAGING SEQUENCE	00 02 03	00 00 00	
SRB JETTISON	00 02 05	00 00 00	
ORBITER/ET ASCENT			
VERIFY ENGINE THRUST	00 02 06	00 00 04	
REACH 3G	00 07 13	00 00 00	
ORBITER MAIN ENGINE CUTOFF (MECO)	00 08 04	00 00 00	
ORBITER-ET SEPARATION			
OPEN FORWARD RCS COVERS	00 08 04	00 00 22	
ET STRUCTUUAL RELEASE	00 08 26	00 00 00	
PERFORM RCS SEPARATION ELEV	00 08 26	00 00 08	
ORBITER MANEUVER (RCS) TO OMS BURN ATTITUDE AND COAST	00 08 34	00 00 15	
● INITIAL ORBIT INSERTION			
PERFORM OMS BURN	00 08 49	00 01 06	
PERFORM MPS LO2 DUMP	00 08 59	00 02 30	
ORBIT INSERTION-OMS SHUTDOWN	00 09 55	00 00 00	INSERTION ORBIT IS 50 x 100 N.MI 93 x 182 km
● COAST TO APOGEE			
DISARM OMS-VERIFY ORBIT INSERTION PARAMETERS	00 09 55	00 00 15	
SELECT ORBITAL RATE MODE	00 10 10	00 00 10	
PURGE MPS ENGINE	00 11 39	00 00 10	
PERFORM MPS LH2 DUMP	00 11 49	00 00 40	
VERIFY MPS DUMP COMPLETE	00 12 29	00 00 10	
SECURE MPS ENGINE	00 12 39	00 00 15	
POSITION MPS ENGINE FOR DEORBIT	00 12 54	00 00 30	
DEACTIVATE APU'S	00 13 24	00 00 15	
OPEN PAYLOAD BAY DOORS	00 13 51	00 04 00	MAY HAVE TO BE DE-LAYED UNTIL AFTER CIRCULARIZATION
ACTIVATE PAYLOAD MONITORING AND CONTROL FUNCTION	00 14 01	00 00 30	

Table 4.1-2. Mission Ascent Timeline (Cont.)
(Rendezvous with 12-Hour Phasing)

MISSION PHASE SUBPHASE EVENT/OPERATION	MISSION G.E.T.	DURATION	REMARKS & COMMENTS
INITIALIZE STAR TRACKERS	00 14:30	00 00 10	
SELECT WIDE DEADBAND	00 14:40	00 00 10	3.0 DEG. DEADBAND
ORIENT TO TARGET STAR FIELD	00 15:00	00 03 00	
PERFORM IMU ALIGNMENT	00 18:00	00 15 00	
ACTIVATE RADIATOR COOLING	00 19:10	00 00 00	
● CIRCULARIZATION			
ORIENT TO OMS BURN ATTITUDE	00 24 18	00 03 00	
SELECT INERTIAL ATTITUDE HOLD	00 27 18	00 00 10	1.0 DEG. DEADBAND
PERFORM PRETHRUST FUNCTION	00 30 00	00 02 00	
SELECT NARROW DEADBAND	00 33 38	00 00 10	0.5 DEG. DEADBAND
ENABLE ENGINE IGNITION CIRCUIT	00 33 48	00 00 10	
PERFORM OMS BURN ΔV = 91 fps = 28 m/s	00 34 18	00 00 56	RESULTANT ORBIT IS 182 x 182 km. 100 x 100 N.MI (Start Phasing) 12 HRS
POST THRUST FUNCTIONS	00 36 00	00 00 30	
NULL RESIDUAL VELOCITY	00 38 00	00 00 10	
DISABLE ENGINE IGNITION CIRCUIT	00 39 00	00 00 15	
SELECT WIDE DEADBAND	00 40 00	00 00 10	
● ORBIT AND P.L. CHECKOUT WITH GROUND STATIONS	00 43 00	03 45 00	
PERFORM IMU ALIGNMENT	03 00 00	03:03:00	
PLANE CHANGE (IF REQUIRED)	03 10 00		
PERFORM IMU ALIGNMENT	10:21:38		
PERFORM PHASING CORRECTION (IF REQUIRED)	11:06:08		
OMS burn attitude maneuver	12:24:k8	00:03:00	

Table 4.1-2. Mission Ascent Timeline (Cont.)
(Rendezvous with 12-Hour Phasing)

MISSION PHASE SUBPHASE EVENT/OPERATION	MISSION G.E.T.	DURATION	REMARKS & COMMENTS
OMS BURN HEIGHT MANEUVER 1 ΔV = 246 fps = 75m/sec	12:34:18	00:05:00*	RESULTANT ORBIT is 100 x 240 N.MI
OMS BURN ATTITU..E MANEUVER	10:09:35	00:03:00	182 x 444 km
1st COELLIPTIC BURN ΔV = 244 fps = 74 m/s	13:19:35	00:05:00*	RESULTANT ORBIT IS 240 x 240 N.MI 444 x 440 km
OMS BURN ATTITUDE MANEUVER	15:31:20	00:03:00	
CORRECTIVE COMBINATION BURN ΔV = 21 fps 6.4 m/sec	15:41:20	00:00:26*	
OMS BURN ATTITUDE MANEUVER	16:08:20	00:03:00	
2nd COELLIPTIC BURN ΔV = 21 fps 6.4 m/sec	16:18:20	00:00:26*	
START RENDEZVOUS PHASE	16:18:50	03:02:45	
TPI ATTITUDE MANEUVER TPI BURN	17:09:50 17:19:50	00:03:00	
1st BRAKING BURN	17:51:20		SIX BREAKING MANEUVERS ΔV ≈ 1.5 m/sec each
LAST BRAKING GATE	17:56:05		30 m from target
HARD DOCK	18:21:35		ORBIT ALTITUDE IS 250 x 250 N.MI 463 x 463 km
START OPERATIONS	19:21:35		

* SINGLE OMS ENGINE BURN

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN.	SEC	HR	MIN.	SEC
1. ASCENT TO INSERTION	00	00	00	00	09	55

The Shuttle launch is assumed to occur from KSC on an azimuth of 90°. The orbiter is launched into an initial orbit of 93×182 km with an inclination of 28.5 degrees. Solid rocket booster (SRB) staging is performed at 00:02:05 G.E.T. at an altitude of approximately 140,000 feet. The SRB is jettisoned to impact into the Atlantic Ocean approximately 117 nmi down range. Ascent of the mated orbiter/ET continues to main engine cutoff (MECO) at 00:08:04 G.E.T. The ET separation sequence requires 45 seconds from MECO to OMS ignition. The sequence consists of opening the forward RCS doors, activation of all thrusters, structural/plumbing/electrical orbiter/ET tie releases, translation of the orbiter away from the ET by means of an 8-fps RCS $-Z$, ΔV, a delta pitch maneuver, and OMS ignition. The dual OMS burn is of 44 seconds duration, sufficient to insert the orbiter into a 93×182 km orbit at 00:09:55 G.E.T.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN.	SEC	HR	MIN.	SEC
2. COAST TO APOGEE	00	09	55	00	14	23

Main engine propellants trapped in the orbiter lines after ET separation are dumped—LOX first and then LH_2—commencing shortly after OMS insertion burn ignition. Dumping, purging, and vacuum inerting the lines require 300 seconds. After the main valves have been closed, the APU's are shut down at 00:13:24 G.E.T. The star tracker and cargo bay doors are opened immediately after completing clearing of the MPS lines. The EGLSS water boiler is then deactivated and cooling is subsequently provided by the radiators.

3. IMU ALIGNMENT

An IMU alignment is performed next by maneuvering the orbiter sufficiently to acquire three star sightings. It is estimated that the alignment can be performed in three minutes. A navigation update is performed at any convenient time during this period using the one-way doppler technique and any available STDN station.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN.	SEC	HR	MIN.	SEC
4. ORBIT CIRCULARIZATION	00	24	18	00	10	10

At 00:24:18 G.E.T., the orbiter maneuvers to OMS burn attitude. OMS ignition occurs at 00:34:18. The burn is a horizontal in-plane posigrade of 28 m/s, lasting 56 seconds, which circularizes the orbit at 182×182 km.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN.	SEC	HR	MIN.	SEC
5. PHASING	00	34	18	11	50	00

After circularization, the orbiter commences a phasing period to reach the proper position for rendezvous initiation. No specific attitude constraints are imposed other than those necessary for thermal conditioning. An IMU alignment using the star trackers is performed preceding each course correction, and navigation updates are acquired by one-way doppler on a station-available basis. A plane change, if required to correct insertion errors, would be performed at 03:10:00 G.E.T.

An IMU alignment is made and, if necessary, a phasing correction maneuver is performed at 11:06:08 G.E.T.

6. HEIGHT ADJUSTMENT

The orbiter commences to maneuver to the required OMS burn attitude for the first of four height adjustments at 12:29:18 G.E.T., ten minutes prior to OMS ignition. All of these four OMS burns are posigrade, performed heads down with the thrust/sector essentially in plane. A tabulation of these burns follows. All of these burns are made with a single OMS engine.

Identification	Delta-V	Begin Attitude Maneuver	Ignition	OMS Duration
Height	75 m/s	12:24:18	12:34:18	5:00
Coelliptic	74 m/s	13:09:35	13:19:35	5:00
Corrective	6.9 m/s	15:31:20	15:41:20	00:26
Coelliptic	6.4 m/s	16:08:20	16:18:20	00:26

On completion of the listed burns, the orbiter will have transferred from the 182-km phasing orbit to a 463-km circular orbit 18 km less than that of the target satellite. At the last OMS cutoff, the orbiter will be both behind and below the target at a line-of-sight distance of about 152 km.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN.	SEC	HR	MIN.	SEC
7. RENDEZVOUS	16	18	20	01	37	45

Immediately subsequent to the last coelliptic OMS burn, the orbiter is maneuvered to an attitude with the -Z axis pointed forward in the general direction of the target. The rendezvous sensor is deployed, activated, and lock-on the target obtained as soon as possible. The estimated lock-on time is less than two minutes. The target is tracked until the range has decreased to about 50 km and a terminal-phase-initiate (TPI) OMS burn solution derived. At 17:09:50 G.E.T., the orbiter commences to maneuver to the TPI OMS burn attitude. The TPI burn attitude is such that the thrust vector is along the line of sight to the target and is timed to occur when the line of sight is 27 degrees above local horizontal. Subsequent to the TPI OMS burn at 17:19:50,

the orbiter is maneuvered to bring the braking axis and optical sight into line with the target inertial attitude hold and narrow deadband is commanded. The theoretical braking delta-V is 9 m/s. Braking is accomplished in six increments of about 1.5 m/s each, with the first at 17:51:20 G.E.T. Cross-axis corrections are applied at the astronaut's discretion and the total delta-V is estimated at 17 m/s. The last braking gate occurs at 17:56:05 G.E.T. and on completion the orbiter will have achieved a stationkeeping position about 30 m from the target.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN.	SEC	HR	MIN.	SEC
8. BERTHING	17	56	05	00	25	30

On achieving stationkeeping, the ETVP is given a visual inspection to assure that berthing may proceed. The target attitude is such that the berthing port axis is about 45 degrees away from the sun. Berthing aids, such as closed-circuit TV cameras and the manipulator arms, are activated. With the manipulator arm extended, the orbiter next approaches close enough to grapple the target. The fixture/platform assembly will have been stabilized by a libration damping system which is initiated by ground command at an appropriate time prior to launch of the orbiter. The attitude control systems of both the target and the orbiter are then commanded free and the manipulator arm is employed to assist in achieving a hard berth at 18:21:35 G.E.T. A special energy absorbing system may be required in the RMS mechanism or the end effector, unless very slow relative velocities can be assured at time of grapple. However, at this time it is assumed that use of the standard RMS end effector will be feasible. After berthing, the orbiter switches to wide deadband inertial attitude hold. Berthing aids are deactivated and stowed. Berthing has been timed to occur in sunlight although this does not negate use of floodlights to fill shadows.

The RMS is assumed capable of drawing the orbiter and fixture/platform together in order to perform a hard mechanical latching and electrical connection at the base of the construction fixture.

Ascent Timeline

The ascent timeline without rendezvous is essentially the same (see Table 4.1-3). It is assumed that orbiter and any payload checkout with ground stations will still be performed in the 182-km circular orbit before the transfer maneuver to the mission orbit is initiated. The orbiter achieves the 463-km circular mission orbit 5 hours, 45 minutes, and 20 seconds after launch.

Table 4.1-3. Mission Ascent Timeline without Rendezvous

MISSION PHASE SUBPHSE EVENT/OPERATION	MISSION G.E.T	DURATION	REMARKS & COMMENTS
● POWERED ASCENT			
MATED ASCENT			
LIFTOFF	00 00 00	00 00 00	
CLEAR LAUNCH TOWER	00 00 05	00 00 00	LAUNCH TOWER IS ASSUMED TO BE 90 METERS IN HEIGHT
PERFORM PITCH PROGRAM (TRAJ.SHAPING)	00 00 05	00 00 10	
MAXIMUM DYNAMIC PRESSURE	00 00 54	00 00 00	
WATER BOILER ACTIVATION	00 00 45	00 00 00	30 km ALTITUDE UP TO THIS POINT NO ACTIVE COOLANT LOOP
SRB TAILOFF	00 01 53	00 00 05	
SRB-ORBITER/ET SEPARATION			
BEGIN ORBITER TVC	00 02 00	00 00 00	
INITIATE SRB STAGING SEQUENCE	00 02 03	00 00 00	
SRB JETTISON	00 02 05	00 00 00	
ORBITER/ET ASCENT			
VERIFY ENGINE THRUST	00 02 06	00 00 04	
REACH 3G	00 07 13	00 00 00	
ORBITER MAIN ENGINE CUTOFF (MECO)	00 08 04	00 00 00	
ORBITER-ET SEPARATION			
OPEN FORWARD RCS COVERS	00 08 04	00 00 22	
ET STRUCTURAL RELEASE	00 08 26	00 00 00	
PERFORM RCS SEPARATION ELEV	00 08 26	00 00 08	
ORBITER MANEUVER (RCS) TO OMS BURN ATTITUDE AND COAST	00 08 34	00 00 15	
● INITIAL ORBIT INSERTION			
PERFORM OMS BURN	00 08 49	00 01 06	
PERFORM MPS LO2 DUMP	00 08 59	00 02 30	
ORBIT INSERTION-OMS SHUTDOWN	00 09 55	00 00 00	INSERTION ORBIT 50 x 100 N.MI 93 x 182 km.
● COAST TO APOGEE			
DISARM OMS-VERIFY ORBIT INSERTION PARAMETERS	00 09 55	00 00 15	
SELECT ORBITAL RATE MODE	00 10 10	00 00 10	
PURGE MPS ENGINE	00 11 39	00 00 10	
PERFORM MPS LH2 DUMP	00 11 49	00 00 40	
VERIFY MPS DUMP COMPLETE	00 12 29	00 00 10	
SECURE MPS ENGINE	00 12 39	00 00 15	
POSITION MPS ENGINE FOR DEORBIT	00 12 54	00 00 30	
DEACTIVATE APU'S	00 13 24	00 00 15	
OPEN PAYLOAD BAY DOORS	00 13 51	00 04 00	MAY HAVE TO BE DELAYED UNTIL AFTER CIRCULARIZATION
ACTIVATE PAYLOAD MONITORING AND CONTROL FUNCTION	00 14 01	00 00 30	

Table 4.1-3. Mission Ascent Timeline without Rendezvous (Cont.)

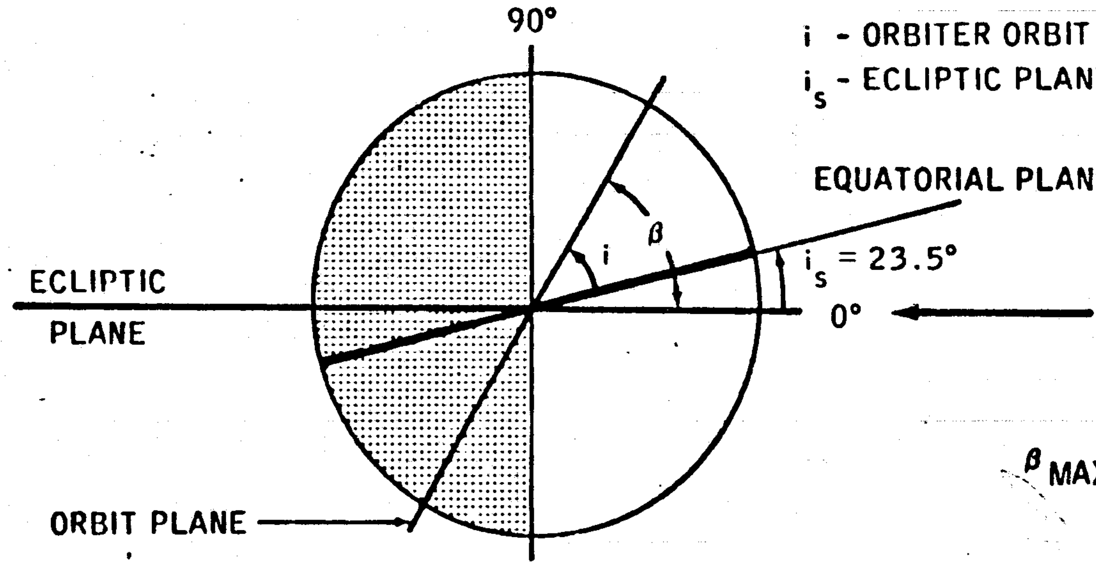
MISSION PHASE SUBPHASE EVENT/OPERATION	MISSION G.E.T	DURATION	REMARKS & COMMENTS
INITIALIZE STAR TRACKERS	00:14:30	00 00 10	
SELECT WIDE DEADBAND	00:14:40	00 00 10	3.0 DEG. DEADBAND
ORIENT TO TARGET STAR FIELD	00:15:00	00 03 00	
PERFORM IMU ALIGNMENT	00:18:00	00 15 00	
ACTIVATE RADIATOR COOLING	00:19:10	00 00 00	
● CIRCULARIZATION			
ORIENT TO OMS BURN ATTITUDE	00:24:18	00 03 00	
SELECT INERTIAL ATTITUDE HOLD	00:27:18	00 00 10	1.0 DEG. DEADBAND
PERFORM PRETHRUST FUNCTION	00:30:00	00 02 00	
SELECT NARROW DEADBAND	00:33:38	00 00 10	0.5 DEG. DEADBAND
ENABLE ENGINE IGNITION CIRCUIT	00:33:48	00 00 10	
PERFORM OMS BURN ΔV=91 fps 28 m/s	00:34:18	00 00	RESULTANT ORBIT IS 100 x 100 N.MI 182 x 182 km
POST THRUST FUNCTIONS	00 36:00	00 00 30	
NULL RESIDUAL VELOCITY	00 38:00	00 00 10	
DISABLE ENGINE IGNITION CIRCUIT	00 39:00	00 00 15	
SELECT WIDE DEADBAND	00 40:00	00 00 10	
● ORBIT AND P.L. CHECKOUT WITH GROUND STATIONS	00 43 00	03 45 00	
● ORBITER READY TO CONTINUE	04:28:00		
IMU ALIGNMENT	04:30:00	00:15:00	
OMS BURN ATTITUDE	04:45:00	00:03:00*	
OMS BURN ΔV=264 fps 80 m/s	04:55:00	00:05:20*	RESULTANT ORBIT IS 100 x 250 n.mi 182 x 463 km
OMS BURN ATTITUDE	05:30:20	00:03:00*	
OMS BURN ΔV= 261 fps 80 m/sec	05:40:20	00:05:20*	RESULTANT ORBIT IS 250 x 250 n. mi 463 x 463 km
● ORBITER IN MISSION ORBIT	05:45:20		

*SINGLE OMS ENGINE BURN

Entry Timeline

The entry phase is comparatively simpler than the ascent phase. The major variable here is the need for thermal conditioning of the orbiter prior to entry. The maximum time for this phase is 12 hours (Figure 4.1-3). However, considerably shorter time periods have been employed in other analyses.

Entry timeline showing a five-hour thermal conditioning or barbecue phase is shown in Table 4.1-4. Note that the event times assume that completion of rollout is the reference time zero, and that the events are listed in reverse chronological order from top to bottom of the table. All times shown are from completion of the roll at touchdown. Just as for the ascent profile, the events are based on a nominal representative entry profile. A detailed description of the events occurring during this period follows.



β - SOLAR INCIDENCE ANGLE, DEG

i - ORBITER ORBIT INCLINATION, DEG

i_s - ECLIPTIC PLANE INCLINATION, DEG

$\beta_{MAX} = \pm (i + 23.5)$, DEG.

β RANGE DEGREES	ORBITER ORIENTATION	HOLD CAPABILITY HOURS	PREENTRY THERMAL CONDITIONING REQUIREMENTS HOURS
0 TO 60	ANY	≥160	≤12
60 TO 90	A. OTHER THAN 3-AXIS INERTIAL HOLDS	CYCLES OF 6-HOUR HOLDS FOLLOWED BY 3 HOURS OF THERMAL CONDITIONING FOR WORST THERMAL ATTITUDES	≤7
	B. 3-AXIS INERTIAL HOLDS	≥160	≤12

Figure 4.1-3. Orbiter Attitude-Hold Capabilities

Table 4.1-4. Entry Timeline

Complete roll	00:00:00
Rollout	00:02:00
At 16000 ft 4.9 km	00:04:39
At 47000 ft 14 km	00:07:55
At 100000 ft 30 km	00:12:36
Entry 400000 ft 122 km	00:38:07
Entry burn	01:11:35
Maneuver to burn attitude	o1:21:35
IMU Alignment	01:36:35
Thermal Conditioning Mode	06:36:35
IMU Alignment	06:20:35
RCS Maneuver ΔV = 1 m/s	08:06:35
Separation (undocking)	08:26:35

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN	SEC	HR	MIN	SEC
1. SEPARATION	08	26	35	01	50	00

After completion of operations, unberthing occurs at 08:26:35 and is accomplished with use of the manipulator arm. After release of the manipulator arm from construction fixture, a minimal RCS pulse is used to start the orbiter moving away from the platform. At 08:06:35, the orbiter RCS jets are used to generate a posigrade ΔV of 1 m/s. During the ensueing revolution the orbiter first moves ahead, then above, and then drifts behind the platform a distance of about 15 km. During this drifting-away period, visual observation of the platform is maintained. The IMU is aligned using the star trackers at a convenient time during this period, and the state vector is updated using the one-way doppler technique and any available STDN station.

	PHASE START G.E.T. HR	MIN	SEC	PHASE DURATION HR	MIN	SEC
2. THERMAL CONDITIONING	06	36	35	05	15	00

All loose equipment is secured and stored, and fuel cell water is dumped. If necessary, the orbiter may be operated in a thermal barbecue mode for up to 12 hours at the end of this phase to minimize thermal gradients. A five-hour barbecue mode is shown here. The orbiter is next configured for deorbit including closing of cargo doors, forward RCS doors, and star tracker's protective doors. The APU's are activated for two minutes and the aerosurface controls checked.

	PHASE START G.E.T. HR	MIN	SEC	PHASE DURATION HR	MIN	SEC
3. DEORBIT	01	21	35	00	43	28

At 01:21:35, the orbiter maneuvers to the deorbit burn attitude, retrograde, heads-down. A single OMS engine is used with ignition at 01:11:35. Burn time is 411 seconds and resultant ΔV is 110 m/s. The orbiter is then maneuvered to a heads-up, nose-first, pitch-up attitude specified for entry interface.

	PHASE START G.E.T. HR	MIN	SEC	PHASE DURATION HR	MIN	SEC
4. ENTRY	00	38	07	00	30	12

The orbiter passes through 122 km altitude at 00:38:07. The APU's are activated and aero surfaces powered. Throughout the remainder of the entry the GN&C steers to reach the landing site and controls to minimize accelerations and thermal heating. The ammonia boiler is activated as the orbiter passes through 30 km altitude at 00:12:36. Entry is completed as the orbiter passes over the minimum energy point (MEP) at approximately 14 km altitude at 00:07:55.

	PHASE START G.E.T. HR	MIN	SEC	PHASE DURATION HR	MIN	SEC
5. DESCENT	00	07	55	00	03	16

The orbiter maneuvers as it descends under control based on terminal area energy management (TAEM). It acquires the projection of the final approach trajectory at approximately 4.9 km altitude at 00:04:39.

	PHASE START G.E.T. HR	MIN	SEC	PHASE DURATION HR	MIN	SEC
6. FINAL APPROACH	00	04	39	00	02	39

Final approach, like the descent, is entirely nominal.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN	SEC	HR	MIN	SEC
7. ROLLOUT	00	02	00	00	02	00

Landing rollout is complete at 00:00:00.

	PHASE START G.E.T.			PHASE DURATION		
	HR	MIN	SEC	HR	MIN	SEC
8. POST-LANDING	00	00	00	00	13	00

GSO hookup requires 13 minutes to the point where the fuel cells may be shut down.

4.2 ORBITER FUNCTIONS

The basic construction facility is assumed to be the Space Shuttle orbiter vehicle, together with modifications described later. The orbiter provides stabilization and control (as required to initiate construction), housekeeping functions, various mission support services (utilities), and accommodations for crew habitability, command, and control. Such functional capabilities have a significant impact on what can be built, how long it takes to build, what crew size can be used, and what costs of constructions may be incurred. Guidelines and assumptions pertinent to construction analysis are presented and discussed in the following sections.

4.2.1 Stabilization and Control

It is assumed that the nominal construction periods will be conducted under free-drift conditions. That is, no active RCS firings by the orbiter or construction fixture will be considered. During the first mission, rotational rate control will be limited to that inherent in the final residual stabilization of the orbiter as it assumes its orbital position for construction. During the first mission and all later missions the rotational rates will also depend on the combination of mass properties, relative motions, and drag effects of the combined orbiter and platform as the platform is being constructed. Analysis was conducted during the first part of this space construction system analysis to establish typical rates and attitudes for a similar (but larger) platform. The results indicated a probability of slow libration rates, which appear to be acceptable for crew operations and construction activity (Reference 4-2). By similarity, such acceptable rates are assumed applicable for this analysis.

4.2.2 Mission Support Services

In the concept for construction of the ETVP, it is assumed that the orbiter provides several essential support services—some directly applicable to construction, and some indirectly related. Table 4.2-1 lists these services and their uses in construction.

Table 4.2-1. Orbiter Support Services for Space Construction

SERVICE	SPACE CONSTRUCTION USAGE
ELECTRICAL POWER • 7 kW MAXIMUM, CONTINUOUSLY • 12 kW FOR 15 MINUTES WITHIN 3-HR PERIODS • 28 VDC	OPERATE CONSTRUCTION MACHINERY, ELECTRICAL HEATERS, LIGHTS ON CONSTRUCTION EQUIPMENT, AND SENSORS; PROVIDE FOR CONTROL AND DATA HANDLING FOR CONSTRUCTION
ILLUMINATION • SEVEN 200-W LAMPS IN PAYLOAD BAY • ONE 200-W DOCKING LAMP • ONE 173-W RMS WRIST CAMERA	ASSIST IN LOCATING, GRAPPLING, TRANSPORTING, AND STOWING CONSTRUCTION EQUIPMENT AND MATERIALS; ASSIST INSPECTION AND CHECKOUT. POWER FOR THESE LIGHTS IS CHARGED TO PAYLOAD (CONSTR.) OPERATIONS.
CLOSED-CIRCUIT TV, CAMERAS, DISPLAYS, AND CONTROL SYSTEMS • RMS • FORWARD BULKHEAD • AFT BULKHEAD	ASSIST IN GUIDING RMS AND OTHER DEVICES, OBSERVING CONSTRUCTION PROCESSES; POWER FOR THE RMS TV's AND THEIR ASSOCIATED HEATERS AND TILT/PAN MECHANISMS IS CHARGED TO PAYLOAD.
ELECTRICAL SIGNAL WIRE PATHS AND SWITCHING CONTROL	CONSTRUCTION OPERATIONS COMMAND AND CONTROL, DATA RECORDING
RF COMMUNICATIONS	STATUS REPORTS TO GROUND; REMOTE CONTROL OF STABILIZATION AND CHECKOUT FUNCTIONS; EVA—CABIN COORDINATION & SAFETY MONITORING
BREATHING OXYGEN, N_2 AND ATMOSPHERIC PRESSURE FOR CREW	SUPPORT CREW FOR IVA CONSTRUCTION OPERATIONS AND RECHARGE EMU PRESSURE SUITS, MMU
WATER (FROM FUEL CELLS)	WATER FOR CREW METABOLIC/ PHYSIOLOGICAL NEEDS; COOLING FOR CABIN
COMPUTATION	SUPPORT CONSTRUCTION OPERATIONS THROUGH EXECUTIVE CONTROL OF MICROPROCESSORS
GUIDANCE/NAVIGATION	INFORMATION ON ATTITUDE, ALTITUDE, AND ROLL RATES

4.2.3 Crew Accommodations

The crew accommodations in the Space Shuttle orbiter provide limited on-site living quarters for construction workers. For purposes of this analysis, the basic volume constraints, seating, and sleeping provisions outlined in Volume XIV (Reference 2) have been assumed. These assumptions are briefly summarized in Table 4.2-2. Figure 4.2-1 illustrates the configurations assumed as potential provisions for up to seven crew members. Figure 4.2-2 illustrates the configuration assumed for the aft flight deck.

Table 4.2-2. Crew Accommodation Assumptions for Space Construction using the Orbiter

Item	Assumption
Nominal crew seating—ascent	7
Baseline crew (weight allowance)	4
Baseline stowage capacity	28 man-days
Cabin nominal maximum stowage volume capacity	42 man-days
Cabin pressure, normal	14.7 psi (10.14 N/cm^2)
Cabin atmosphere	20% O_2 , 80% N_2
Galley	Installed
Hygiene accommodations	Installed
Nominal EVA storage	Two suits
Airlock—two-man capacity	Installed—internal configuration
Aft flight deck	Standard—workspace for 4 persons

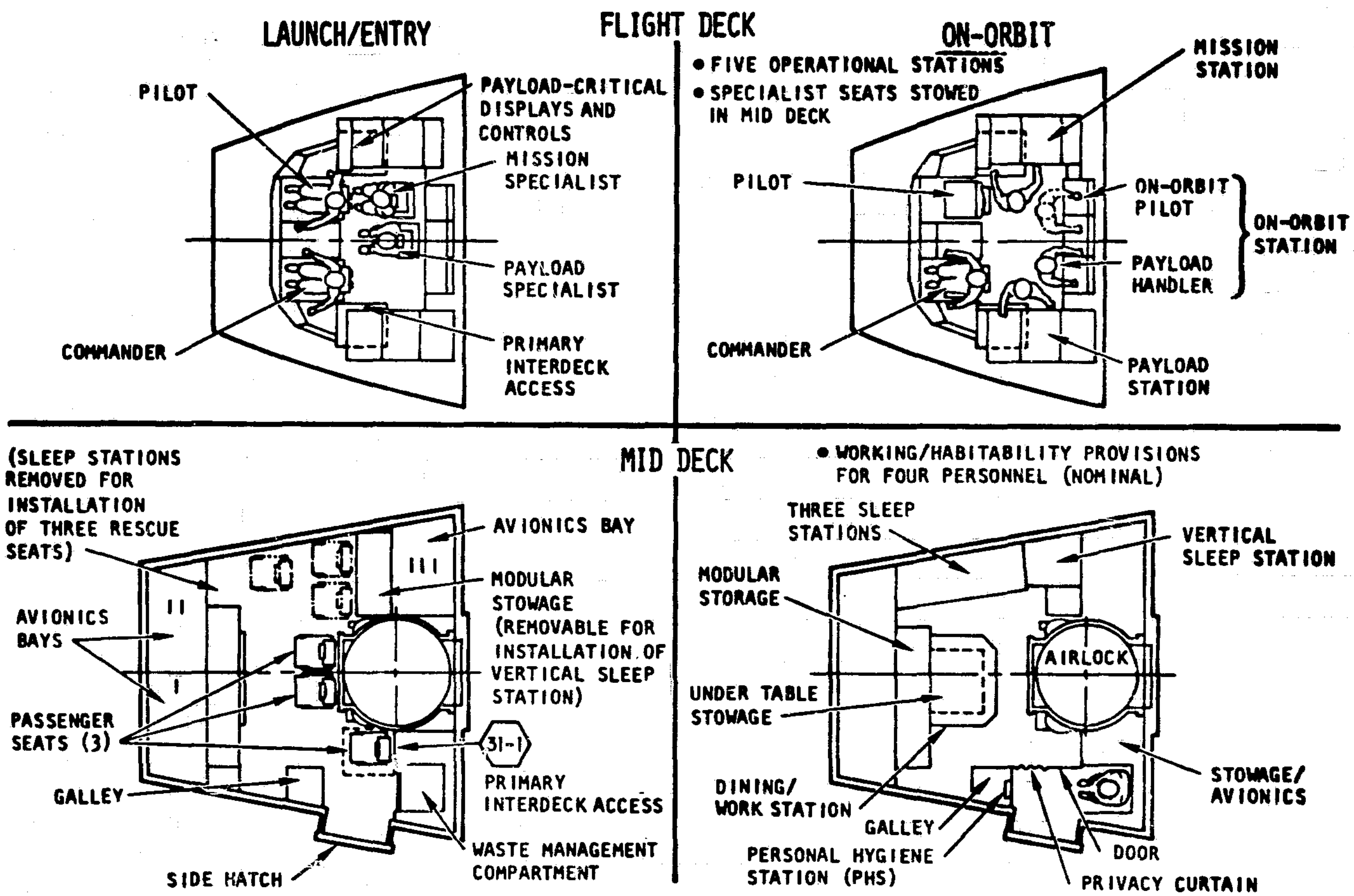


Figure 4.2-1. Crew Cabin Arrangement

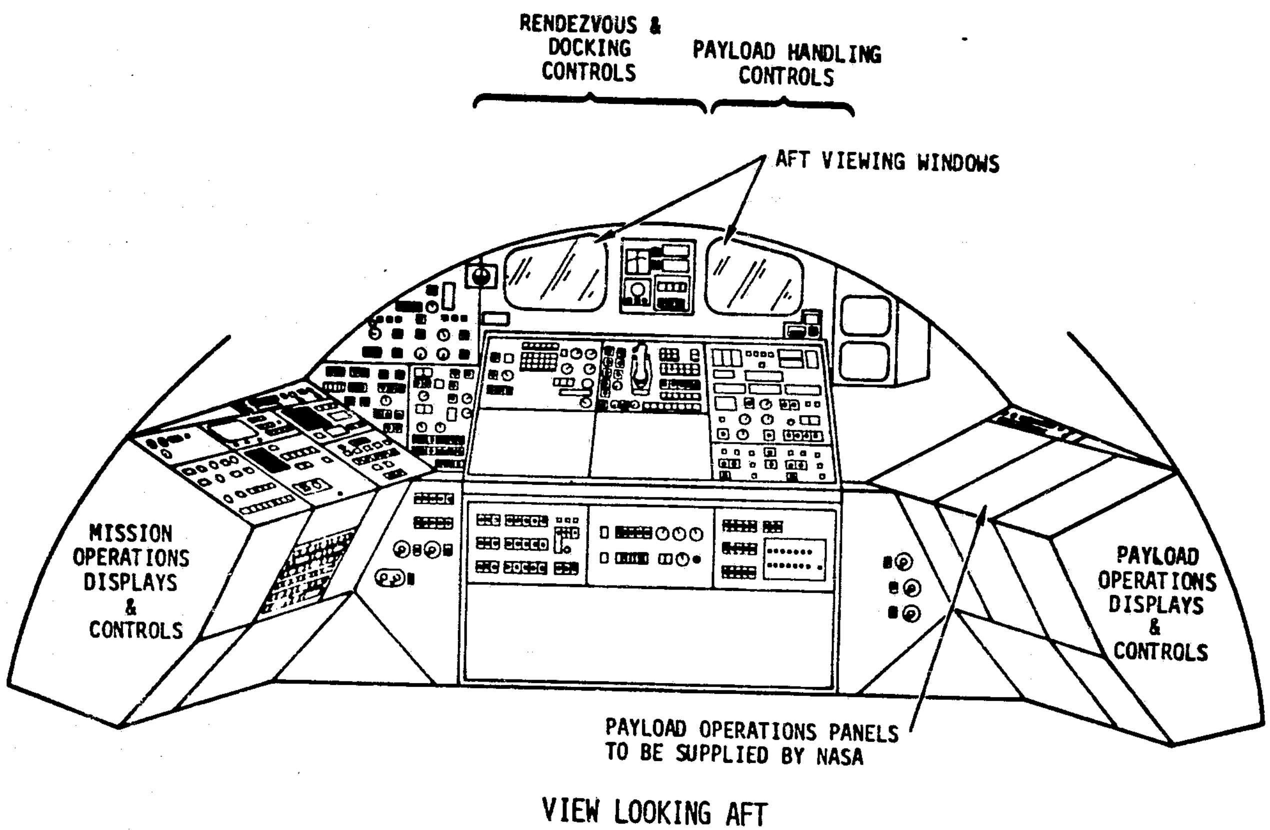


Figure 4.2-2. Aft Flight Deck Configuration

4.3 CREW FUNCTIONS

The following guidelines and assumptions regarding crew functions relate primarily to the construction operations periods. The specific concerns are divided into those associated with the EVA and IVA physical situations, the timelines and procedures related to work/rest cycles, and those related to crew skills and assignments.

4.3.1 EVA Requirements

This section describes guidelines and assumptions dealing primarily with hardware and supplies for EVA. Crew timelines for EVA are considered in Section 4.3.3. Table 4.3-1 lists the major pertinent guidelines and assumptions relative to EVA operations hardware and supplies. The major impact on this set of equipment may come from introduction of a high-pressure suit (8 psi). Such a suit may require additional volume for stowage as well as revisions for the higher pressures. Also, the larger than standard number of suits required to support three shifts of EVA operations almost certainly would require stowage provisions in the payload bay for suits. Each EVA egress could also include fetching one or more such suits and placing the suit(s) into the airlock prior to repressurization.

Table 4.3-1. Guidelines and Assumptions for
EVA Construction Operations Hardware and Supplies

- Extra (more than two) EVA suits may be stowed in the payload bay and retrieved for use by the EVA person upon egress.
- If required, to extend stowage capacity, additional LiOH, food, and other supplies may be stowed in the payload bay and retrieved by EVA
- A standard orbiter airlock and plumbing shall be provided, located internally to the crew cabin. Selective modifications may be required for the use of high-pressure (8-psi) suits.
- Two crewmen may occupy the airlock at the same time while wearing high-pressure suits and associated portable life support systems.
- The airlock shall be closed and repressurized after egress by an EVA crew member, so as to permit suit doffing of a returned EVA crew member, and suit donning by the crew member scheduled for the next shift.
- Individually assigned suits shall be provided for each designated EVA crew member and his designated IVA or EVA backup crew member. Nominally, the IVA backup crew is the IVA crew person performing construction operations. However, alternate designations may be made—such as a separate standby IVA crew member prebreathing 100% oxygen, or an exterior EVA "buddy."
- Additional nitrogen tanks shall be supplied for multiple repressurizations above the nominal baseline orbiter provisions of two. Each tank set provides for 4.5 repressurizations.

Whenever possible, depressurization and repressurization cycles include one (or more) crew ingressing as well as one (or more) egressing in order to minimize demands for gas supplies.

Contingency operations involving EVA were not studied in this analysis. It is recognized that such studies would result in detail requirements for additional hand rails, tethers, foot restraints, and other mobility aids on the construction equipment and the flight support equipment.

4.3.2 IVA Requirements

Guidelines and assumptions relative to physical provisions for intravehicular construction operations are listed in Table 4.3-2. Crew habitability accommodations guidelines and assumptions were included in Section 4.2.4.

Table 4.3-2. Guidelines and Assumptions for IVA Construction Operations Hardware and Supplies

- The IVA construction operations shall be conducted primarily in the aft flight deck of the orbiter crew cabin using standard window provisions, control and display consoles, crew restraints, and accommodations.
- Console space provisions and wiring options dedicated to payload operations shall be utilized for controls and displays unique to the construction operations. These may be different for each mission.
- The standard orbiter RMS controls and displays shall be modified as required to incorporate the upper arm roll joint capability and tilt/pan capability of the camera.

In general, this study identified no unusual requirements for the crew aft flight deck accommodations. However, detailed analyses of controls and displays requirements, microprocessors, and software programs were not undertaken. It is assumed that time-shared displays and controls can be utilized, since the construction processes tend to be grouped in serial phases of operations. Such an approach will reduce the need for extensive area dedicated to controls and displays for the many primary control and backup construction functions such as latches, heaters, checkout, lights, cameras, transporters, etc.

4.3.3 Crew Work/Rest Cycles

This section deals primarily with guidelines and assumptions specific to developing timelines for crew work/rest cycles. The key items of concern are listed in Table 4.3-3. These include considerations of IVA and EVA operations and their interactions. Options are listed for using low-pressure suits (4 psi) or high-pressure suits (8 psi or equivalent, which requires no prebreathing operations). Although the latter type of suit system is recommended and used as a baseline for analysis, it was felt useful to indicate the assumptions used for the selection.

Table 4.3-3. Guidelines and Assumptions for Crew Work/Rest Cycles During Construction

- The crew will follow a 16-hr awake/8-hr sleep cycle.
- The crew workday is normally 10 hours, but may be extended to 11 hours for a few days (3 or 4).
- There will be 3/4-hour per day schedule for pre-sleep and post-sleep activities (1-1/2 hours total).
- All crewmen will be awake for all major burns.
- The crew meal periods will be scheduled for one hour at least twice per day.
- No scheduled exercise is planned for flights less than one week's duration.
- Crewmen will sleep and work in shifts as required.
- Designated sleeping volumes may be serially occupied by different crew members during a 24-hour cycle of multi-shift operations. Sleeping bags may be personal equipment items, rolled and stowed by each crew member at end of each of his sleep periods.
- Scheduled IVA crew activities will be allotted a minimum of 5 minutes duration and rounded off to 5-minute increments.
- Orbiter housekeeping duties are assumed to require no more than two hours and twenty minutes per 24 hours.
- EVA and equipment-related activities are allotted a minimum of one minute increments.
- EVA crew will have an average of at least 10 minutes rest per hour, preferably after 45 to 50 minutes work, and 20 minutes for a lunch (candy bar).
- Cabin crew works when EVA crew is outside and coordinates breaks with EVA schedule.
- EVA by a single crew member shall be permitted. However, an IVA crew member shall be available at all times to engage in rescue operations.
- For pressure suit operations at 4 psi, prebreathing of 100% O_2 shall be required for three hours prior to egress.
- IVA backup (rescue) crew shall not breathe 100% oxygen for more than six hours on a regular daily basis.
- Crew members required to prebreathe oxygen will be supplied with walk-around oxygen equipment permitting voice communication and minimal interference with orbiter housekeeping duties. IVA operations of RMS or control/display panels can be performed while prebreathing.
- EVA crew wearing 4-psi pressure suits is limited to six hours of external operations per 24-hour period. Pre- and post-EVA procedures are per orbiter standards.

Table 4.3-3. Guidelines and Assumptions for Crew Work/Rest Cycles During Construction (Cont.)

- EVA suit donning and doffing are each allotted 1.5 hours (total of 3 hours per EVA) for all types of suits.
- For pressure suit operations at 8 psi (or approximately one-half the cabin atmosphere pressure), prebreathing of 100% O_2 is not required.
- EVA periods of 8 hours are permitted by use of higher capacity portable life support systems or umbilicals to on-site supplies when using 8-psi pressure suits.
- No assembly activities or EVA activities are performed during orbiter translation from one assembly location to subsequent location.

4.3.4 Crew Assignments, Proficiency, and Training

Table 4.3-4 lists guidelines and assumptions pertinent to crew assignments for the subject space construction analysis.

Table 4.3-4. Assumptions Related to Crew Assignments

- Each mission will have a designated commander, pilot, and mission specialist trained to handle the respective functions for ascent, rendezvous, berthing separation, deorbit, entry, and landing.
- IVA crew members are cross-trained to perform all required IVA crew functions and EVA rescue operations for the mission.
- EVA crew members are cross-trained to perform all EVA functions required for the mission.
- All crew members are trained to perform routine orbiter housekeeping functions.
- All crew members are trained to perform some aspect of construction and are considered part of the normal space construction crew complement.

Discussion of crew assignments in regard to space construction tends to raise the general question of skills selection for such repetitive "blue collar" type of activity. There is a considerable amount of repetitive activity to be considered in this construction project. However, it is doubtful these repetitions are so extensive for any one shift of operations in this particular project as to be unacceptable for pilot-trained crew members. Hindsight available at the time of this writing reveals that very few shift operations are required for any given crew member. It is concluded that special effort to select crew personnel who are tolerant of extended repetitive effort is not justified. Skills in time management, understanding of electronics, and mechanics of the construction process are probably the most critical concerns. However, physical skills in handling tools and performing close-tolerance assembly are indeed essential for the EVA operations. Special skills and special training to develop proficiency in IVA operations of the RMS and EVA operation involving the cherry picker are also essential.

Therefore, minimization of training costs suggests that crew assignments should be coordinated with specific skills and training. It is assumed that such has been the case for these analyses.

In preparations for space construction operations, funds and equipment must be allocated for crew training to develop a reasonable degree of proficiency in specific construction skills and overall procedures. This training improves productivity and enhances crew safety. It has been assumed for the analyses described later that the crew has received such adequate training. Possible increases in productivity due to on-site learning gained during the mission have not been incorporated into the timeline analyses although strong evidence for such improvements has resulted from Skylab experience. It was felt that the current accuracy of timeline predictions did not justify such fine-tuning of estimates.

4.4 BASIC CONSTRUCTION SUPPORT EQUIPMENT

The construction analysis is based upon use of certain basic, multipurpose support equipment items (some with appropriate modifications) which are being developed, or at least seriously studied, as likely candidates for future space operations. The major items include a manned maneuvering unit (MMU), open cherry picker version of a manned remote work station (MRWS), remote manipulator system (RMS), and beam builder machine. These baseline items of equipment and system components are described in the following pages to provide a basic understanding of the intended performance capabilities and configurations, and the assumptions upon which later modifications for space construction are based.

4.4.1 Manned Maneuvering Unit (MMU)

The MMU is being developed by the Martin Marietta Corporation. The data presented below have been taken from their Users' Guide for the MMU, dated May, 1978 (MCR 78-517, NAS9-14593).

General

The principal elements of the MMU (Figure 4.4-1) are its basic structure, a propulsion subsystem, two hand controllers, and a control electronics assembly (CEA). Twenty-four fixed-position thrusters utilizing gaseous nitrogen (GN_2) provide full six-degree-of-freedom control by reacting to commands from the three-axis translational hand controller (THC) and the three-axis rotational hand controller (RHC). Electrical power is supplied to the MMU subsystems from two batteries mounted at the top rear of the unit between the GN_2 pressure vessels. Command logic, power conditioning equipment, and gyroscopes are mounted in the control electronics assembly (CEA) located behind and below the batteries.

The MMU is a fail-safe system in that any single failure does not preclude the astronaut from returning safely to the orbiter vehicle. The thrusters are separated into two independent systems (12 thrusters each), each of which provides full six-degree-of-freedom control in the event of a failure in the other system. The control electronics are also redundant such that at least one set of 12 thrusters can always be commanded.

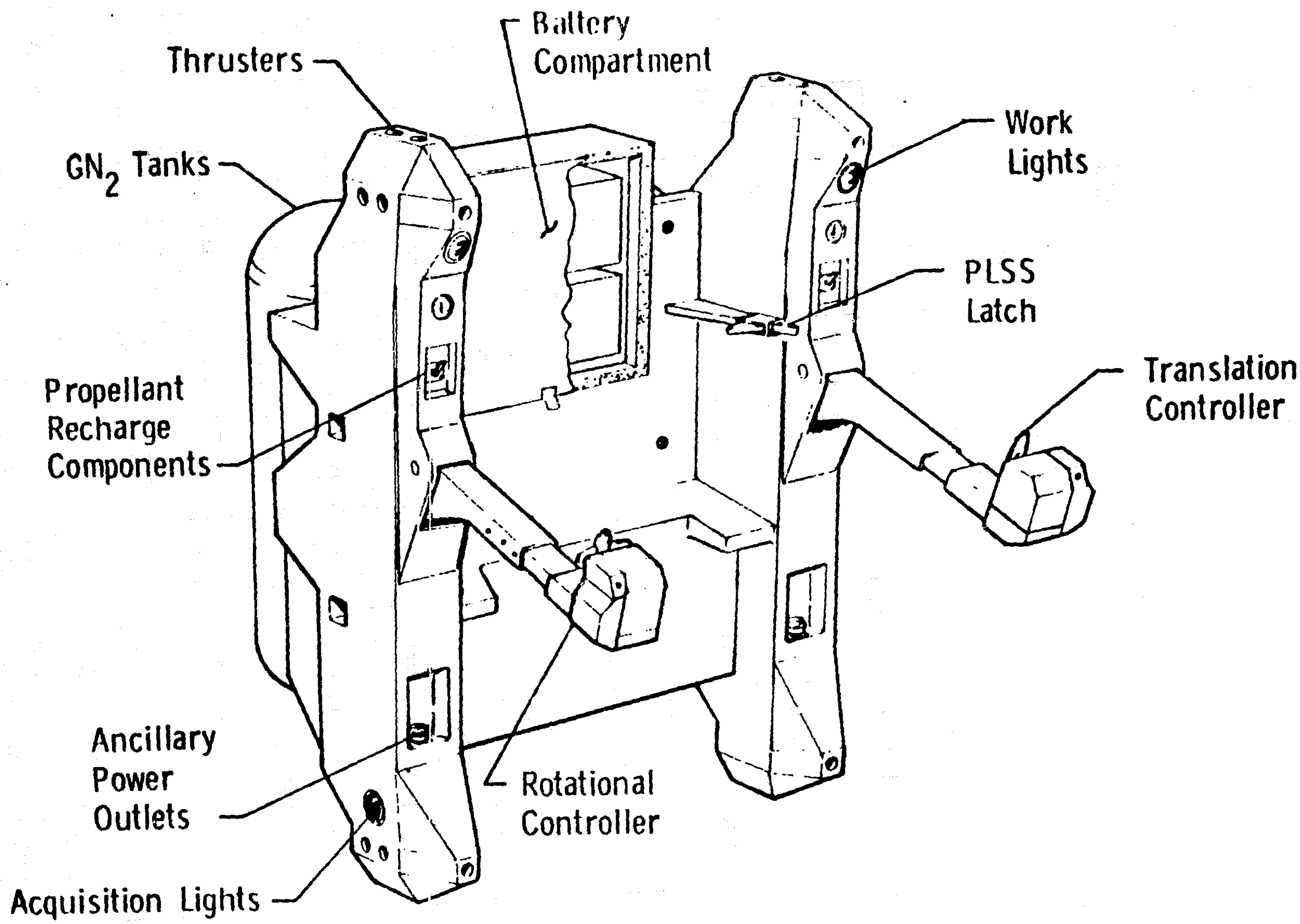


Figure 4.4-1. Manned Maneuvering Unit

In addition to the manual commands which are applied by the astronaut from the hand controllers, an automatic attitude hold (AAH) capability is also available. By activating a switch located on top of the RHC grip, the astronaut can command attitude hold and the MMU will maintain attitude in three axes of rotation by firing thrusters automatically, as required. Three rate gyros sense rotations and attitudes in each rotational axis, and the MMU control logic uses these data to command the thrusters. If rotational rates are already present when attitude hold is commanded, the control logic will fire thrusters to cancel those rates.

The two propellant tanks contain a total of 40 lb (18 kg) of GN_2 at 4500 psia and 70°F, on initial charge on the ground prior to a mission. These pressure vessels are rechargeable during EVA by an unassisted crew member. The initial charge provides sufficient propellant for an equivalent ΔV of 110 to 135 fps; subsequent recharges on orbit will provide a minimum equivalent ΔV of 72 fps (36 fps per GN_2 tank). The control logic of the MMU is designed to maintain fuel consumption from each tank at a relatively even level. In addition, the logic is designed to select the optimum combination of thrusters in order to conserve propellant when mass offsets are present or multiple axis commands occur simultaneously.

The MMU is stowed for launch and reentry in the Flight Support Station (FSS) located in the payload bay of the orbiter (Fig. 4.4-2). The FSS structure provides environmental protection to the MMU during launch, on-orbit (nonoperational) periods, reentry and landing. The FSS also contains the necessary attachment provisions, foot restraints and handholds for donning/doffing and servicing the MMU in orbit by an unassisted EVA crew member. One FSS can be mounted on each side of the payload bay so two MMU's can be carried on each orbiter flight.

Flight Characteristics

The maneuvering unit responds to direct manual commands input by the crew member via the two hand controllers. For a nominal system mass, translation accelerations are 0.3 ± 0.05 ft/sec^2 and rotational accelerations are 10.0 ± 3.0 deg/sec^2. Since the MMU operates in a direct flight mode, these acceleration levels are present whenever either hand controller grip is displaced from the center or null position. Acceleration commands are terminated when the grip is returned to the center position. Simultaneous commands in several axes (multi-axis commands) are possible at reduced acceleration levels.

Each MMU thruster develops approximately 1.4 lb of thrust; therefore, single axis translation commands generate 5.6 lb of thrust in the normal operations mode, and 2.8 lb of thrust in the backup operations mode. Rotational torques are the same for the prime and backup modes. For multi-axis commands up to six thrusters can be firing simultaneously.

The automatic attitude hold (AAH) capability of the MMU allows the crew member to maintain attitude in any or all of the axes of rotation. The MMU control logic automatically fires thrusters as required to hold a position within a deadband of ±0.5 to ±2.0 degrees (premission selectable) in any rotational axis, as sensed by the rate gyros. Drift rates across this deadband (if, for example, the crew member is relatively still while inspecting or photographing a payload) are on the order of 0.02 deg/sec.

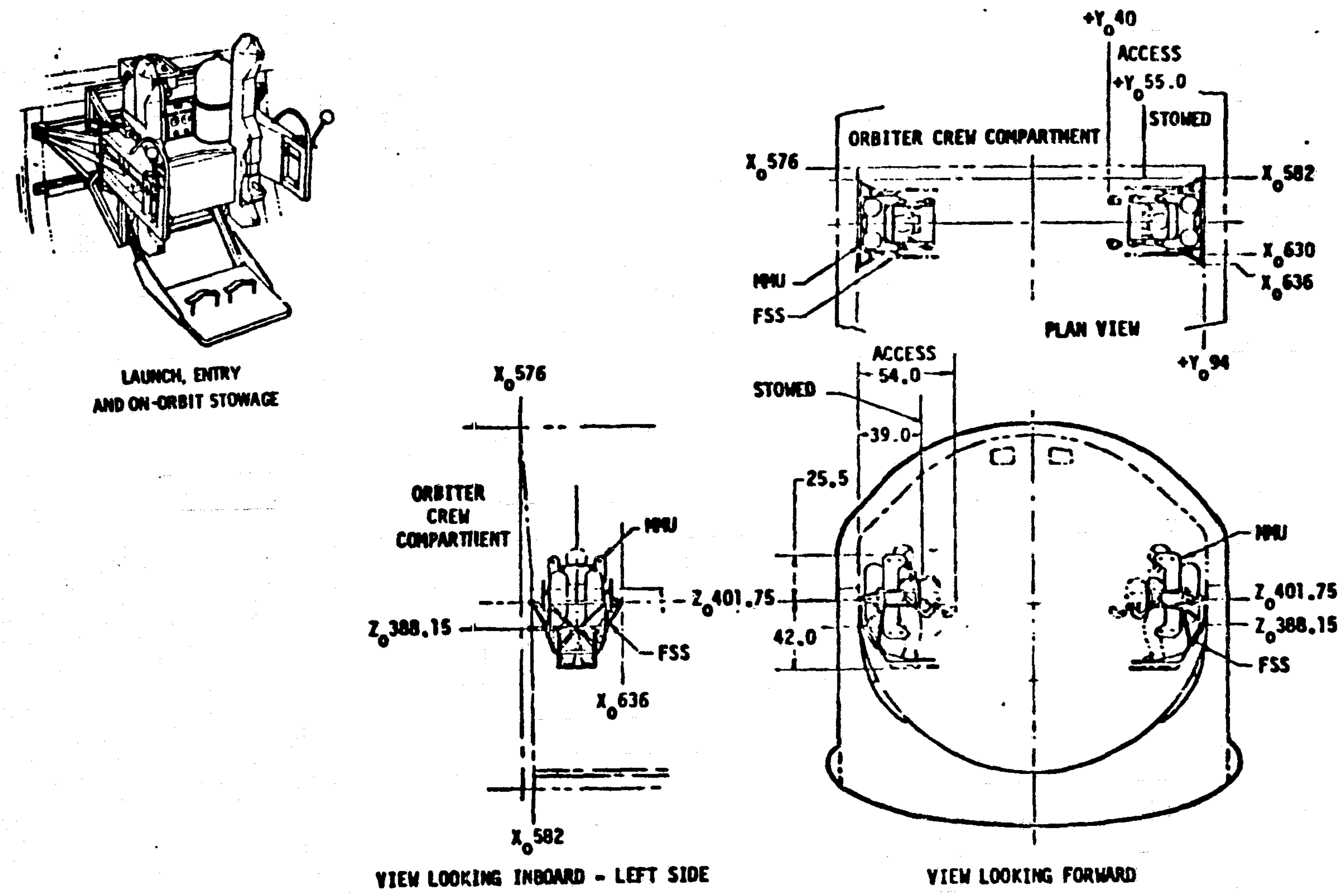


Figure 4.4-2. MMU/FSS Configuration in Payload Bay

In the AAH mode, highly developed control logic incorporating limb motion filters and limited minimum impulse thrust repetition rates allows a tight limit cycle deadband that is relatively insensitive to large crew member limb motions and is fuel conservative in the presence of the cyclic disturbance torques.

Three-axis attitude hold can be commanded during translation in any axis. Attitude hold can be inhibited independently in the roll, pitch or yaw axes when the crew member inputs via the RHC a manual rotation command in that axis.

Table 4.4-1 summarizes the flight characteristics of the MMU.

Table 4.4-1. MMU Flight Characteristics

- Six-Degrees-of-Freedom Control Authority
- Spacecraft-type Piloting Logic
  - 3-Axis Translational Controller (Left Hand)
  - 3-Axis Rotational Controller (Right Hand)
  - Independent or Multiple Axis Commands
  - Pulse or Continuous Commands
- Manual (Direct) Translation and Rotation Control
- Automatic Attitude Hold
  - Deadband Adjustable ± 0.5 to $\pm 2.0^{\circ}$
  - Inertial Drift less than 0.01°/sec
- Response
  - Translational Acceleration 0.3 ± 0.05 ft/sec^2
  - Rotational Acceleration $10.0 \pm 3.0^{\circ}$/sec^2
- Audio Feedback for Thruster Operation

Operational Guidelines

Although the MMU cold gas propulsion system is essentially noncontaminating, the EMU life support system does vent water vapor to space (approximately one pound of water per hour). In almost all cases for specific payload operations, this level and type of contamination is well within acceptable limits.

The MMU cannot be effectively utilized as a stable platform from which large forces and torques can be exerted; that is, the MMU should not be considered a mechanism through which large forces or torques can be reacted to do

work. Additional restraints are required in such cases. The MMU can be utilized, however, to counter light loads such as might occur during simple tasks.

Work Site Aids/Ancillary Equipment

The MMU contains provisions to attach cargo or equipment for transport during maneuvers. These attachments allow the crewmember's hands to remain free to operate the MMU hand controllers. Three types of attachments are available. Telescoping, lockable arms with grappling end effectors can be extended from each side of the MMU to hold cargo in front of and below the hand controllers. Soft tethers can be attached to the cargo and to the pressure suit waist ring, or the side of the MMU. Finally, attachment mechanisms can be mounted at the end of each handcontroller housing to carry a smaller cargo item directly in front of the crew member's hands.

These attachment provisions are generally intended to allow easy transport of relatively small (less than 50 lb) cargo items. The MMU system is capable, however, of transporting larger masses (up to several hundred pounds) when operating free of external forces. The MMU control system compensates for changes in center of gravity and the torques which result from attaching such additional cargo. Exact limiting criteria are dependent on the total task requirements (e.g., distances, time constraints), in addition to the cargo mass and location.

The electrical system of the MMU provides auxiliary power which can be utilized to operate tools or other equipment at the task site, once translation to the site has been accomplished. Two power outlets supply 28V dc and 2 amps maximum; each outlet is operated by a switch accessible to the crewmember in flight. In addition, a floodlight which provides local work site illumination is mounted over each shoulder of the crewmember in the MMU.

Tethers can be utilized to establish a soft attachment between the crewmember/MMU and work site. A temporary system is also available to establish a more rigid attachment between the MMU and the work site. This system is designed to allow the crewmember to apply moderate forces at the work site without generating intolerable reactions or torques. It should be noted that additional work site dedicated restraints may be required if large forces or torques must be applied by the crewmember at the site. These restraints must be supplied by the user, or be built into the work site. A variety of standard Shuttle equipment is available for such support (see JSC-10615, "Shuttle EVA Description and Design Criteria").

The arms on which the MMU hand controllers are mounted can be folded down to provide clearance for the crewmember to approach the work site more closely.

Additional functional capability can be kitted into the MMU if required by a specific operational mission. Additional propellant tanks and navigation aids can be attached to the baseline MMU system to allow extended excursions farther away from the orbiter vehicle. Although design concepts for these kits have not been finalized, potential MMU users should be aware that such capability will become available as part of the basic MMU configuration as the Shuttle flight program progresses.

Servicing

The MMU can be serviced by a single crewmember while it is mounted in the FSS. Spare batteries, stowed in the pressurized crew compartment, can replace used batteries in the MMU; battery replacement takes less than five minutes. Two fully charged batteries provide 540 watt-hours of power; the nominal MMU load is 30 watts. (Battery recharge, if required, is accomplished in the pressurized airlock of the orbiter using the EMU recharge system. Up to 16 hours are required to establish a full charge.)

Recharge of the MMU nitrogen propellant tanks can be performed at the FSS using a pressurized nitrogen supply (3000 psi maximum) available from the orbiter. A quick disconnect establishes the connection between the orbiter supply and the MMU. Gauges and toggle valves mounted on the MMU and FSS are utilized to monitor and control repressurization. Propellant recharge of both tanks can be completed in less than 10 minutes.

Since the orbiter supply (3000 psi maximum) is less than the initial ground charge of the MMU (4500 psi), the delta velocity available from the recharge will typically be 80 to 100 fps. A full ground charge provides 110 to 135 fps delta velocity capability.

Mass Properties

The total weight of the MMU is approximately 243 lb (110 kg), including a full charge of propellant (40 lb GN_2). Fig. 4.4-3 depicts the reference coordinate axis and shows the location of the center of mass of the EMU/MMU system. The maneuvering unit will accommodate personnel within the range of the 5th percentile based on anthropometric data for 1968 USAF women offi cers, to the 95th percentile based on data for 1980 male flying officers.

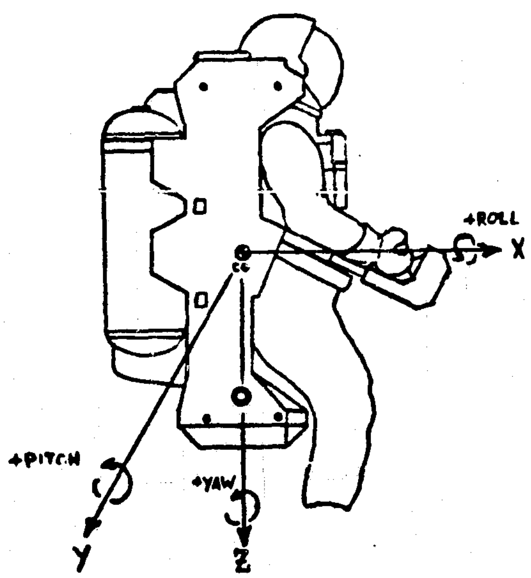


Figure 4.4-3. MMU Reference Coordinate System

For each MMU carried aboard the orbiter, a Flight Support Station (FSS) is required. The FSS is a structure to which the MMU is attached for launch and reentry of the orbiter. The weight of the FSS is approximately 50 lb (23 kg); hence, the payload launch weight penalty for one MMU is approximately 293 lb (133 kg). It should be noted that the weight of the flight operational MMU system includes the astronaut and the extravehicular mobility unit (EMU). The astronaut weight can vary between 100 and 215 lb (45 to 100 kg); the EMU weight is approximately 175 lb (80 kg).

4.4.2 Manned Remote Work Station, MRWS (Cherry Picker)

The MRWS is being developed by the Grumman Corporation. The data presented has been taken from their final report, "Manned Remote Work Station Development Article," Volume I, Book 1, Flight Article Requirements, Report NSS-MR-RP008, dated 3-1-79.

Flight Article System Requirements

The following defines the overall configuration, safety, reliability, maintenance, and interface requirements.

Open Cherry Picker MRWS (Figure 4.4-4)

The MRWS shall support the EVA astroworkers and provide unobstructed reach for the astroworker to perform space tasks. The MRWS shall consist of:

- A platform with a restraint system to secure the EVA astroworker
- Stabilizer attached to the platform
- Illumination
- Stabilizer controls and displays
- RMS controls and displays
- Tool storage (small hand tools)
- Provisions for large tools
- Payload handling devices
- RMS mechanical and electrical interfaces
- Provisions for storage in payload bay

The platform shall be mounted to the orbiter RMS utilizing the stabilizer fixture that interfaces with standard snare-type end effector.

Electrical power, controls, and data shall be routed through the RMS internal cabling utilizing the payload mounted grapple fixture special-purpose end effector connector.

The open cherry picker MRWS shall fold for storage in the orbiter payload bay. Its folded volume shall not exceed 1.5 m^3 and it shall be mounted adjacent to the EVA hatch at the starboard manned maneuvering unit (MMU) donning station attachment points.

Open Cherry Picker Subsystem Requirements

Structure/Mechanical

All major load-carrying structures of the structural subsystems shall be designed to a safe life of a minimum of 10 years in orbit with a scatter factor of 4.0. Life limitations shall be identified.

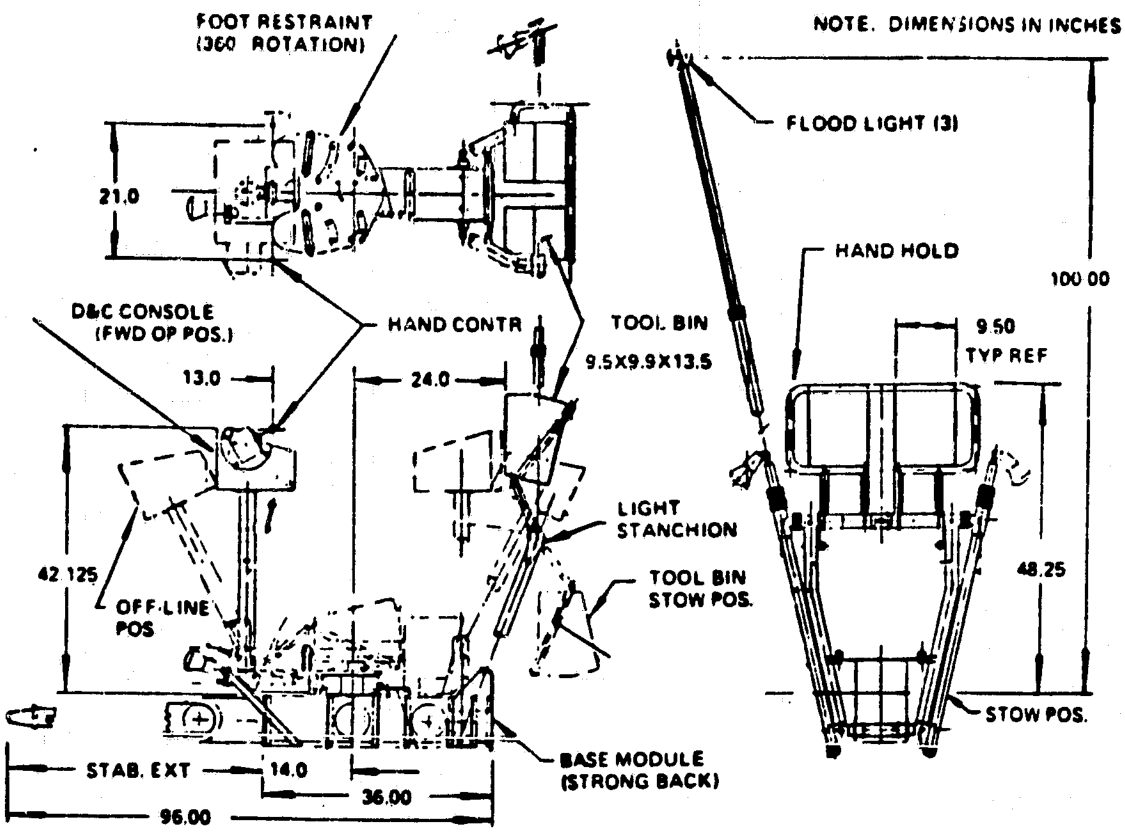


Figure 4.4-4. OCP-DTA General Arrangement

As a goal, fail-safe design concepts shall be applied to all critical structure so that failure of a single structural member shall not degrade the strength of stiffness of the structure to the extent that the crew is in immediate jeopardy.

The structure shall be designed to resist damage resulting from accidental impact during crew activities.

Safety factors used for structural design shall be consistent with those currently used for manned operations.

- Primary Structure
  - Ultimate strength: A factor of 1.5 x limit load shall be applied.
  - Yield strength: A factor of 1.2 x limit load shall be applied.

Structures shall be designed to withstand temperature cycling between -433°K to 366°K.

The structure shall be designed to withstand orbiter launch and landing oads specified in JSC-07700, Volume XIV.

The open cherry picker (OCP) shall be designed to be folded and unfolded by an EVA astronaut to facilitate orbiter payload bay storage.

Communications

The OCP operator shall utilize the EMU for communications with the orbiter, EVA astroworker and space construction base as applicable.

Electrical Power

The open cherry picker MRWS shall receive 28 V dc orbiter power, up to 250 W, via the RMS grapple fixture electrical connector.

The distribution system shall provide circuit protection devices for all power equipment.

The electrical power subsystem (EPS) shall have a maintained lifetime of not less than 10 years. Elements may be replaced in total or in modular form for maintenance or for growth up-rating.

Environmental Control and Life Support (ECLS)

The OCP operator shall utilize the extravehicular mobility unit (EMU) for ECLS.

Thermal Control

Passive thermal control approach should be utilized where appropriate, or if not feasible, the design should minimize system complexity and weight.

The subsystem shall not require selected orientation in orbit to maintain its thermal control function.

Crew Accommodations

An existing foot restraint that is mounted to a rotating platform (Fig. 4.4-5) will be utilized for the OCP.

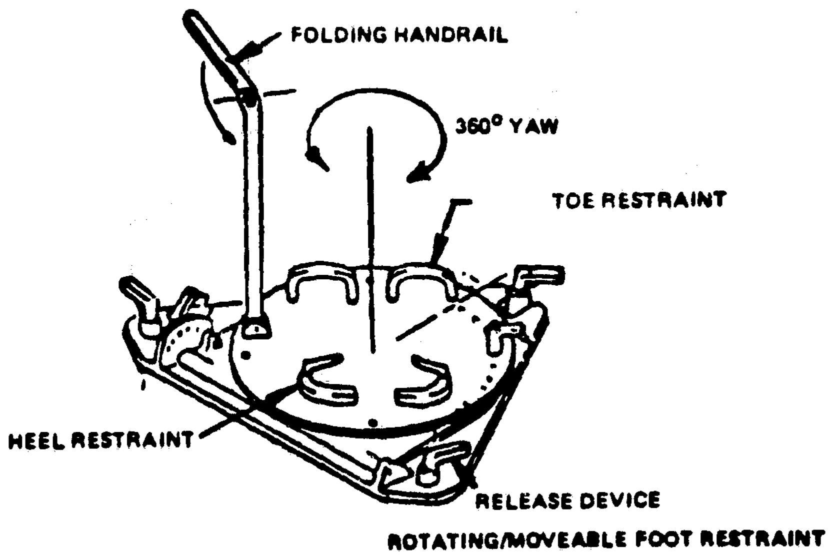


Figure 4.4-5. Foot Restraint

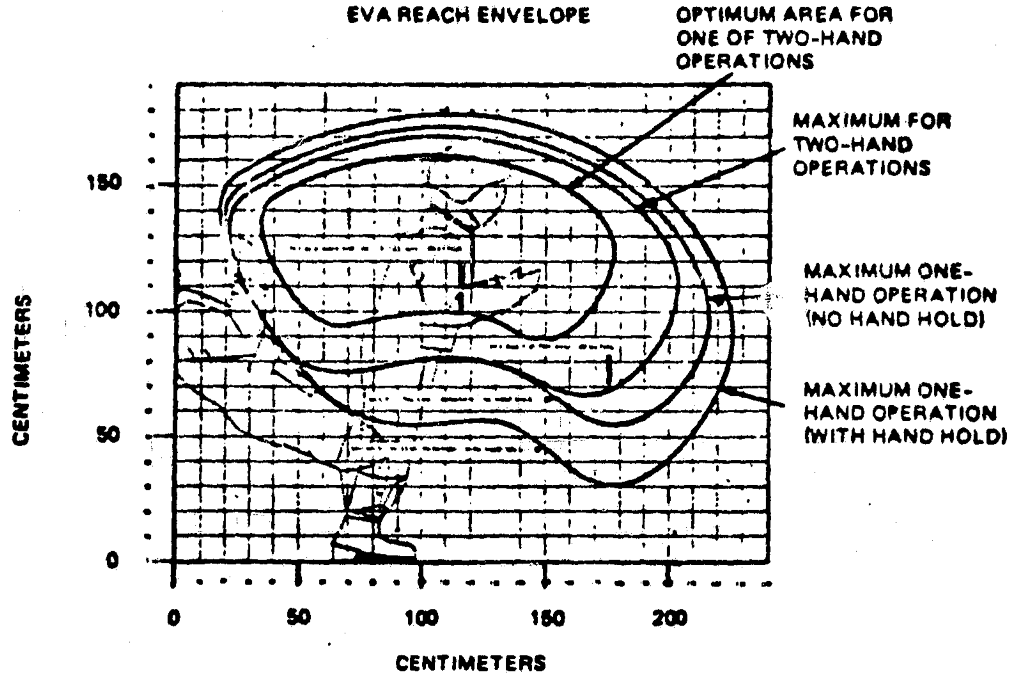
A safety tether shall be provided. Also provided will be a waist restraint to be used in conjunction with foot restraint as needed.

The open platform equipment shall not inhibit crew reach (Fig. 4.4-6) to perform assembly tasks.

Stabilizer (Controller and Slave)

The OCP MRWS shall have one stabilizer located on the platform extending forward and shall be capable of being installed/detached in orbit. The stabilizer shall have 3 DOF as defined in Fig. 4.4-7. The stabilizer characteristics are:

Reach	**1.3 m**
Tip force (locked)	**40 lb**
Tip moment (locked)	**4000 in.-lb**
Accuracy	**± 1 cm**
Resolution	**± 2 mm**
Velocity	**1.1 cm/sec**



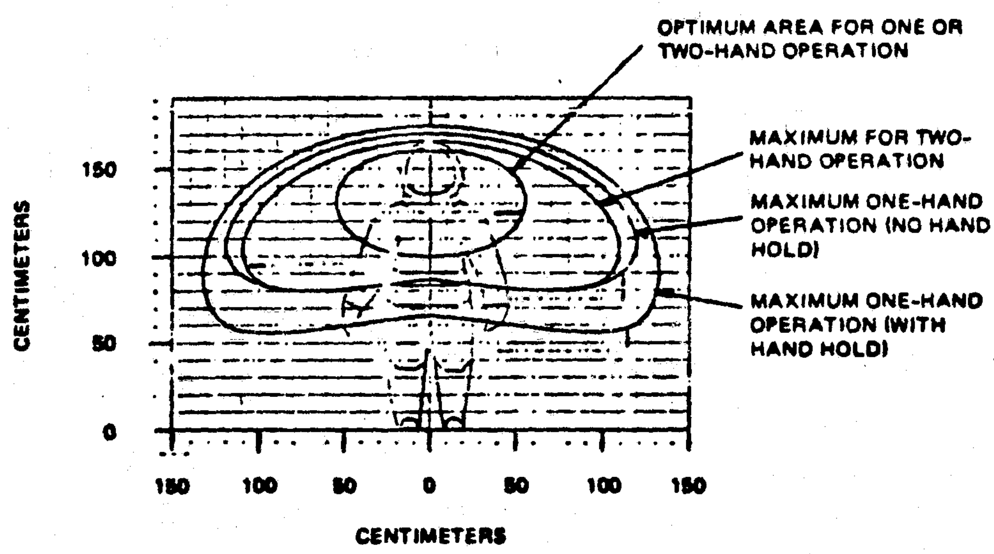


Figure 4.4-6. EMU Reach Capability

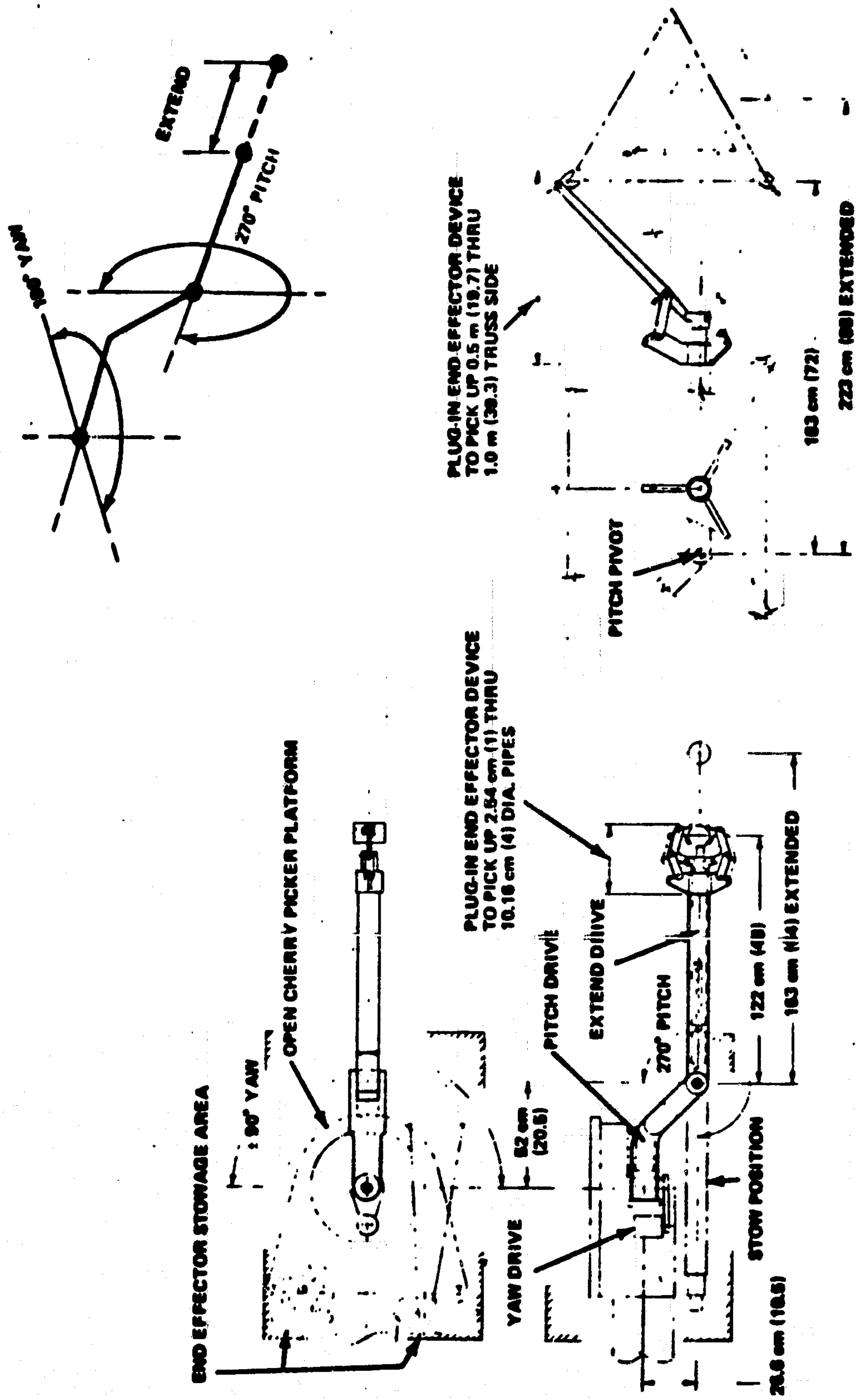


Figure 4.4-7. Three-Degree-Of-Freedom Stabilizer

- The stabilizer master control shall be a resolved rate controller(s)
- The tip shall have mechanical and electrical interfaces to accept end effectors.
- Provide controls to actuate end effector functions, eg., open/close jaws.
- The stabilizer joints shall lock in existing position at power removal.
- Back driving shall not damage the stabilizer.

Cherry Picker Arm Control

- Provide orbiter RMS/cherry picker arm control from the OCP utilizing the same type of controllers used for the orbiter RMS.
- The capability shall be available to select control of an alternate RMS/crane arm.
- The capability shall be available to the OCP operator to control individual RMS joints.
- Interface units shall be provided for open cherry picker RMS control as shown in Figure 4.4-8.

Illumination

Lights shall be mounted on the OCP to provide 50 ft-c of luminous intensity within the reach of the OCP operator. The lights shall be adjustable by the OCP operator for direction and reach.

Controls and Displays (C&D)

A C&D console shall be mounted convenient to the operator during OCP RMS maneuvers and when controlling the stabilizer. The panel shall provide accommodations for mounting the RMS and stabilizer controllers. Controls and displays panel shall be moveable so that the operator is not constrained while performing space tasks.

Software

Utilize existing orbiter software for control of the RMS.

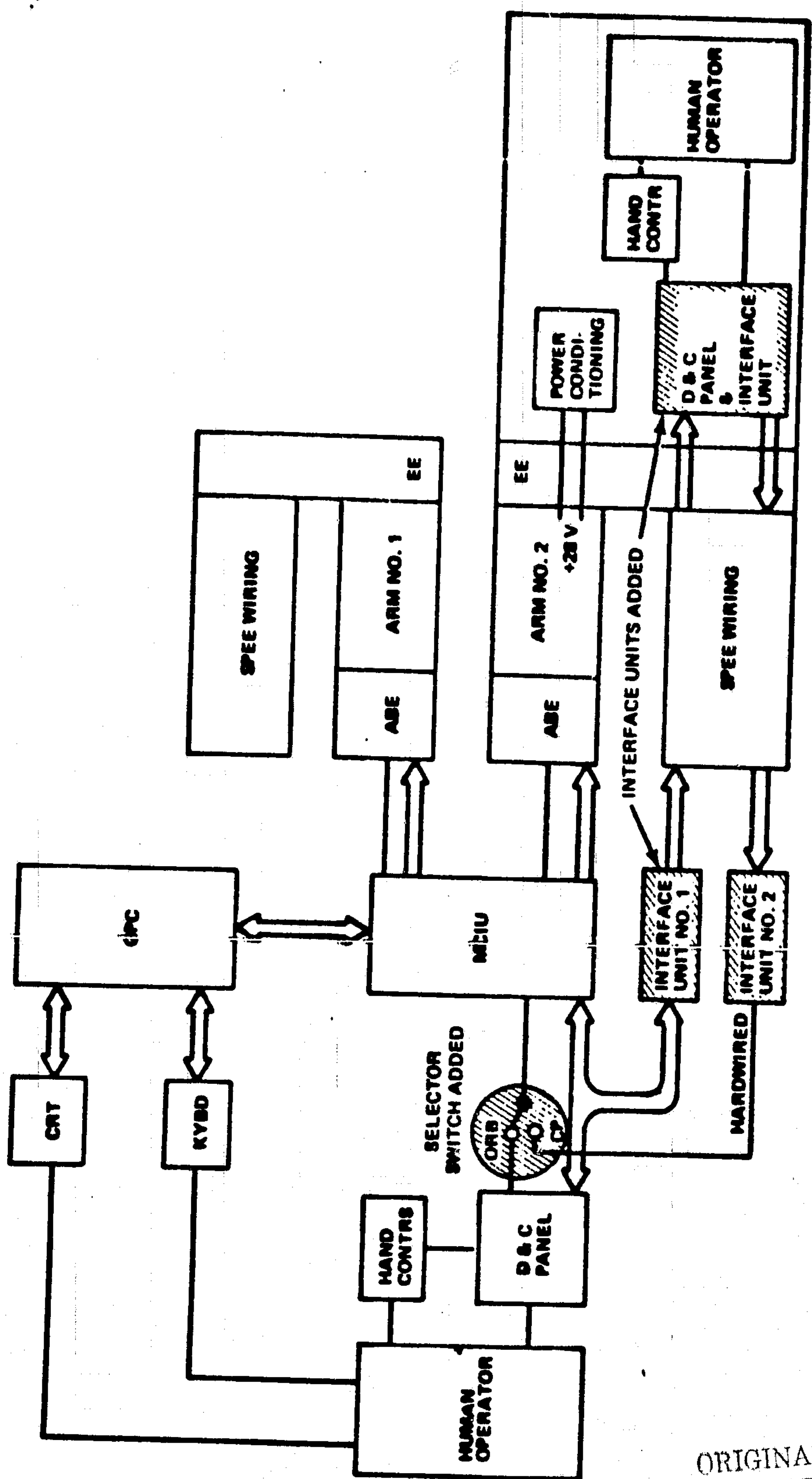


Figure 4.4-8. Orbiter/RMS/OCP Block Diagram

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Remote Manipulator System (RMS)

The RMS is being developed by SPAR of Canada for the Shuttle program. These data have been taken from the Space Shuttle System Payload Accommodations, JSC 07700, Volume XIV, Revision F, dated 9-22-78.

The RMS is shown in Fig. 4.4-9. A single manipulator of 50 feet, 3 inches (15,316 mm) in length is normally located on the port side of the vehicle, as shown in Fig. 4.4-10. The RMS is stowed outside the payload dynamic envelope and is charged to orbiter weight. Detailed arm dimensions and joint angle limits are shown in Fig. 4.4-11.

A second manipulator arm can be installed on the starboard longeron if compatible with STS operational constraints. The weight of the second manipulator is weight chargeable to the payload. This weight is 905 lb, including the standard end effector and TV at the wrist (TV also mounted at the elbow is an additional 28 lb). Capability is provided to operate two manipulators in serial-only (non-simultaneous) operations. Capability is provided to hold the payload with one manipulator arm in a chosen position while operating the second manipulator arm.

The capability is provided to jettison each manipulator arm assembly. Sufficient redundancy is provided to insure that the payload can be released prior to RMS arm jettison.

General RMS Capabilities

a. In orbit, the manipulator is capable of deploying a maximum envelope (approximately 15 feet diameter x 60 feet long), maximum weight 65,000 lb (29,484 kg) payload. Under normal operational conditions, the RMS is capable of retrieving a 32,000-lb (14,515-kg) payload and placing it in a position for engagement with the cargo retention system in the cargo bay for return to earth. Under clearly defined contingency conditions, the RMS is capable of retrieving a maximum weight payload (65,000 lb) in a non-time constrained operation. (The requirement for retrieval of a payload weighing more than 32,000 lb could be to correct a malfunction in the payload and subsequently redeploy the payload. The orbiter entry and landing is normally constrained to payloads weighing less than 32,000 lb.

Deployment of a maximum envelope, maximum weight payload can be accomplished in approximately 25 minutes from release of payload tiedown to release of the payload at the manipulator fully deployed position.

The RMS is capable of supporting up to a maximum weight payload in the preplanned deployed position under the attitude stabilization loads imposed by the orbiter vernier RCS (operating in min impulse mode).

Within the operational reach limits of the manipulator the orbiter vehicle will have the capability to deploy and/or retrieve single or multiple payload elements on orbit during a single flight. Within defined limitations, the RMS may also be used to place payloads on or dock payloads with, a suitably configured and stabilized body.

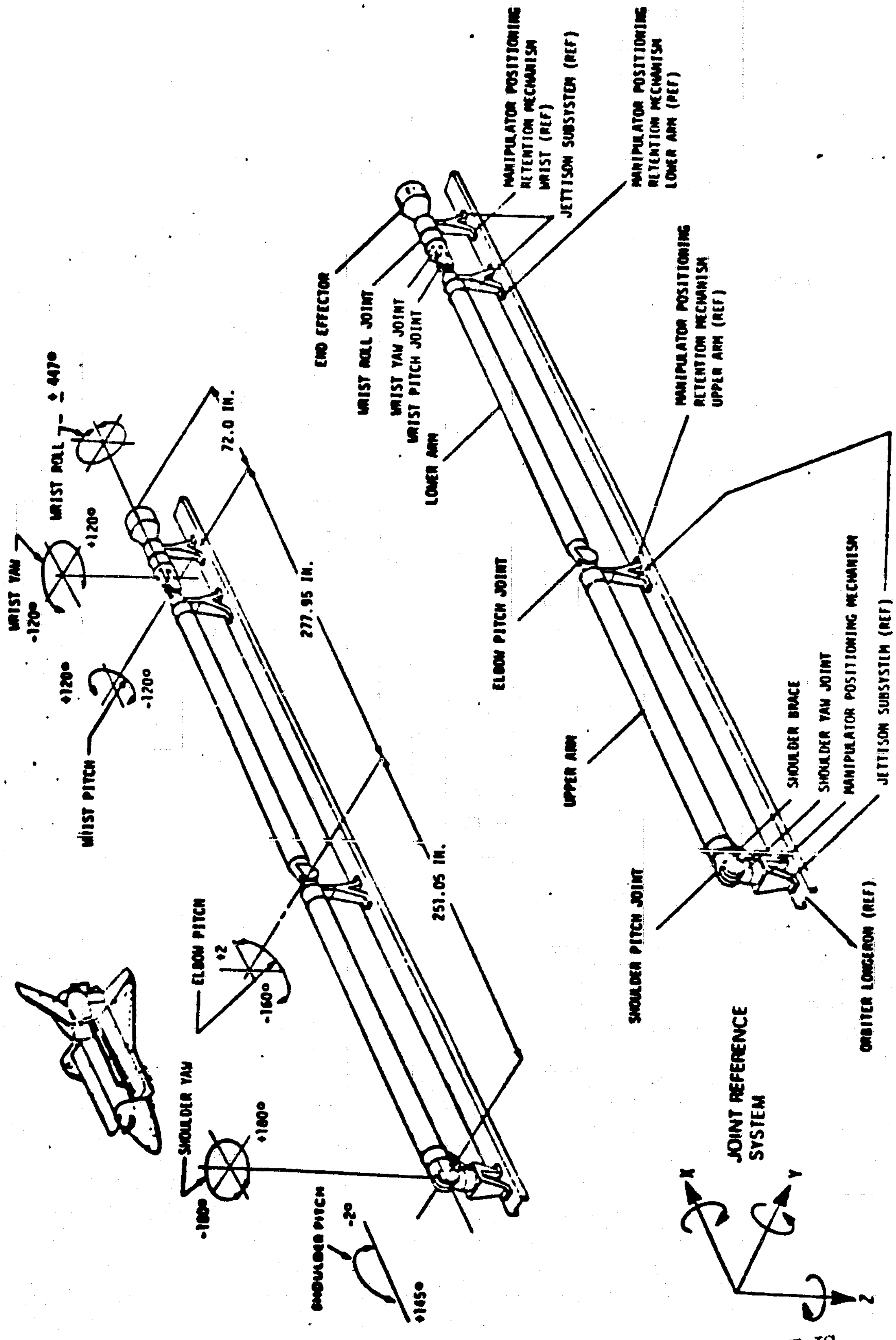

Figure 4.4-9. Orbiter Remote Manipulator System

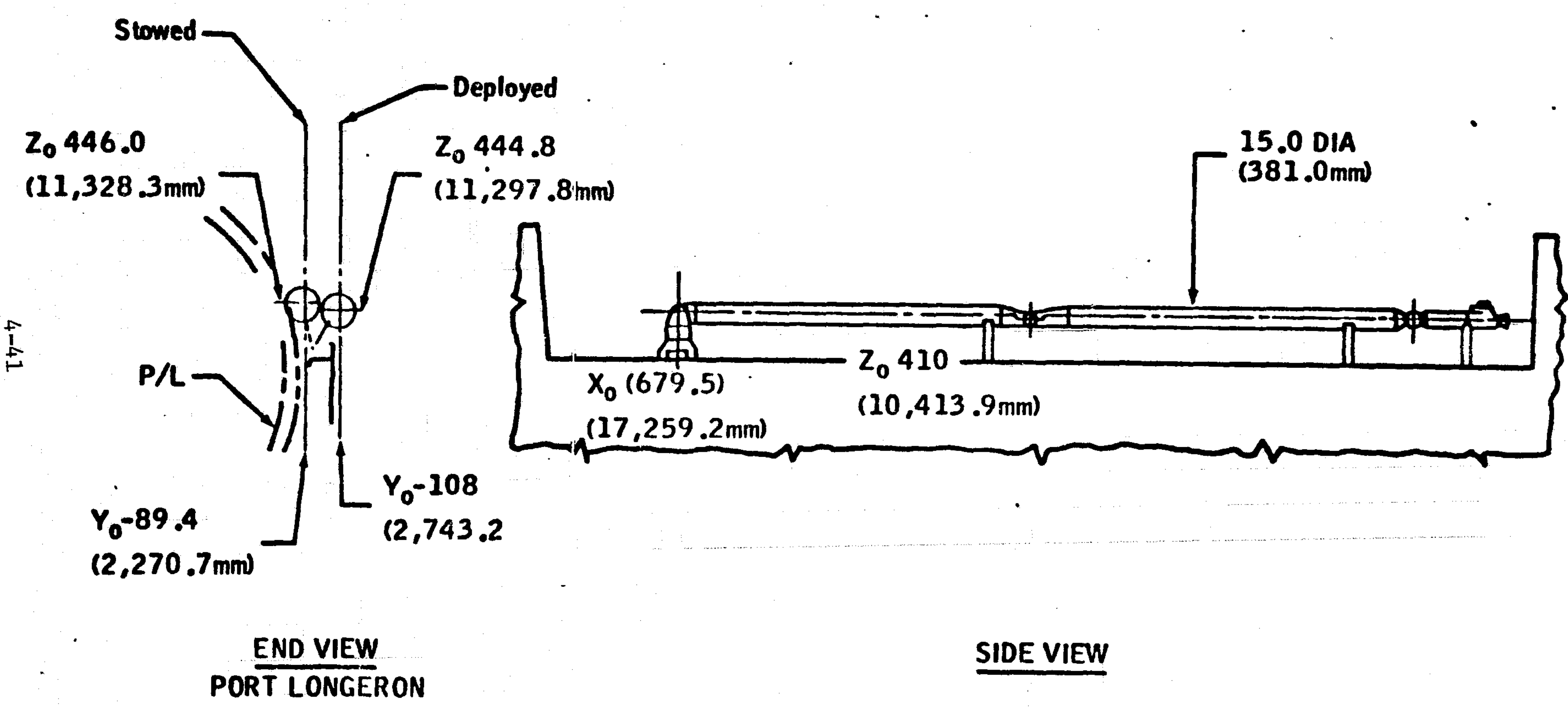

Figure 4.4-10. RMS Location

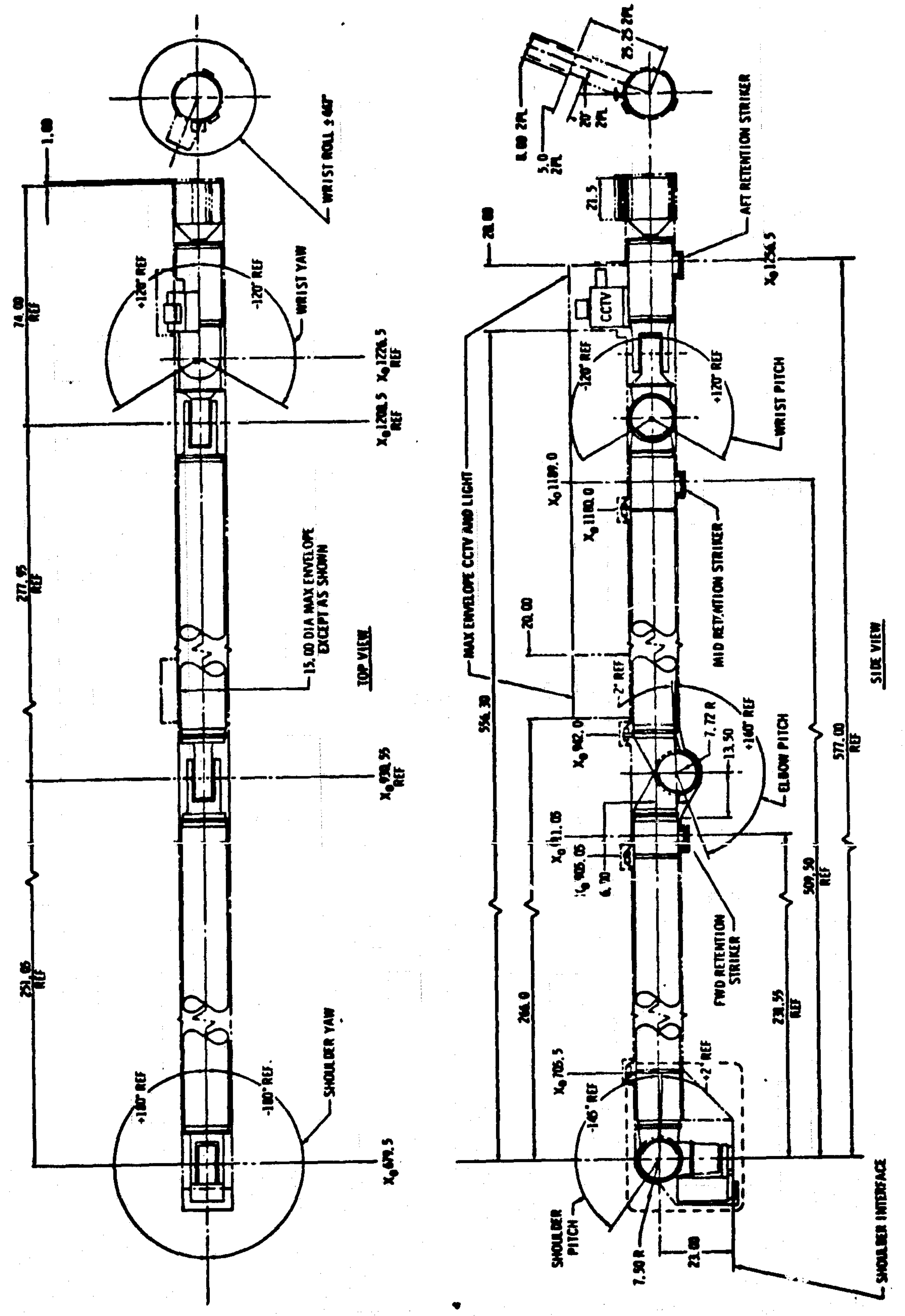

Figure 4.4-11. RMS Arm Dimensions and Joint Angle Limits

b. The standard end effector provided with the RMS and its associated grapple fixture (payload provided) are shown in Figures 4.4-12, -13, and -14. The capture and rigidize sequence is shown in Fig. 4.4-15. The RMS also has the on-orbit capability of grappling a special-purpose end effector (payload provided) and providing an electrical connection across the interface for control of the special end effector. This connection may also be used to provide power and/or signals to payloads, if the payload provides the compliance and mating connector within its grapple fixture. The electrical connector is fitted on the outside of the standard end effector at the end effector/payload interface as indicated in Figure 3-14. The power for the special purpose end effector or payload is taken from the 28 V arm power bus. Wiring is provided from the orbiter flight deck on-orbit station distribution panel to the RMS shoulder interface, and from there to the face of the standard end effector. Controls and displays for command or signals to the special purpose end effector or to payloads must be provided by the payload. The wire gauging and quantities available for this interface are shown in Fig. 4.4-16. On-orbit stowage of any special purpose end effector must be provided by the payloads. The RMS standard end effector may be exchanged on the ground with a special end effector for use on orbit.

RMS Performance Characteristics

The velocity of the loaded RMS end effector is controlled such that the kinetic energy of the payload will not exceed that of a 32,000-lb payload moving at approximately 0.2 ft/sec. The velocity of the unloaded RMS end effector is limited to 2.0 ft/sec.

Within 5 minutes following extension of the RMS/payload and deactivation of the orbiter VRCS, the RMS will be capable of releasing a 32,000-lb maximum envelope payload within the following limits:

- Attitude within 1° of a specified orientation, relative to the RMS shoulder attach point. Attitude relative to orbiter is TBD.
- Position within 2.0 in. of a specified position relative to the RMS shoulder attach point.
- Angular momentum of the payload relative to the orbiter less than or equal to 10 slug-ft^2/sec.
- Linear motion of less than 0.10 ft per second.

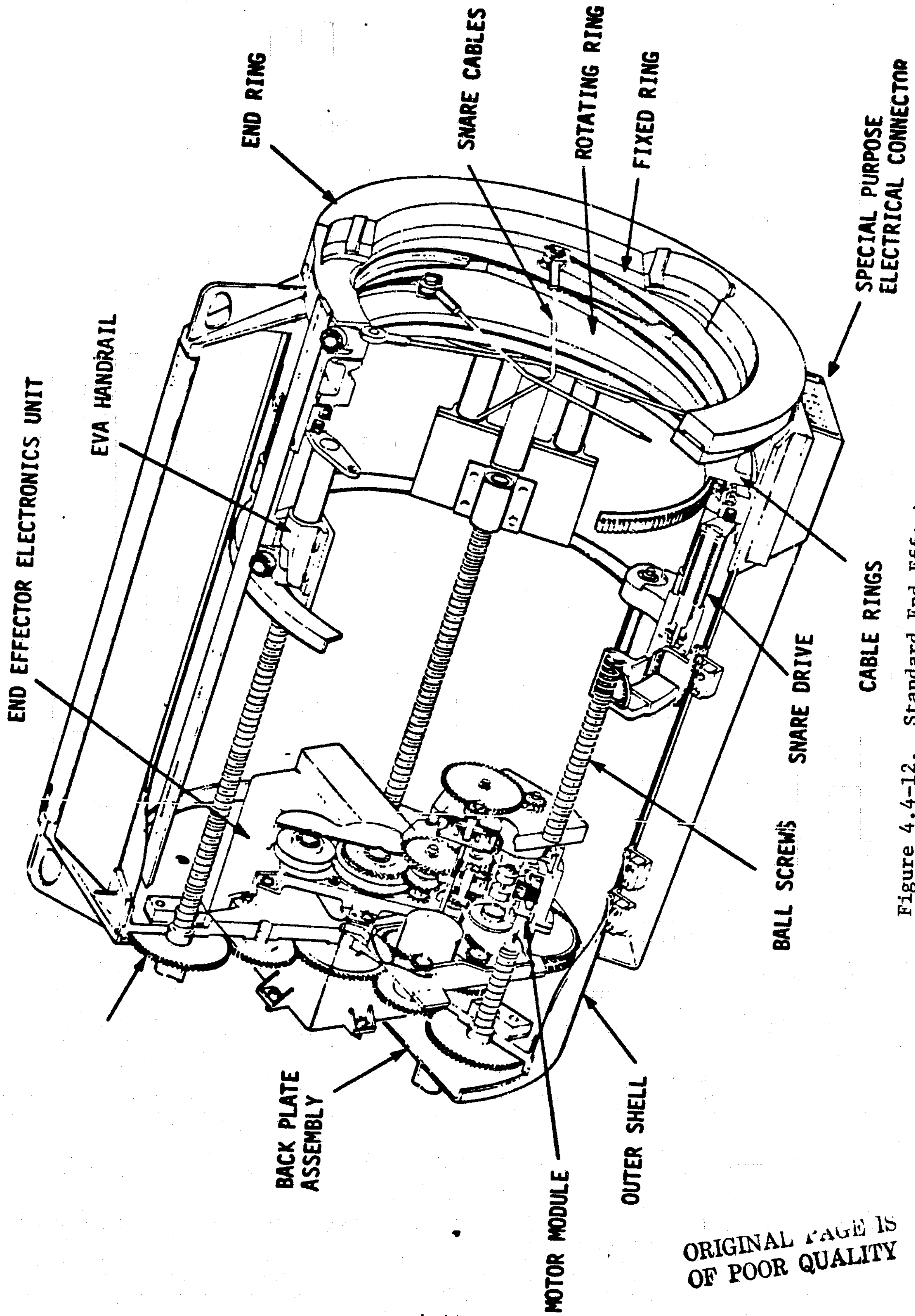

Figure 4.4-12. Standard End Effector

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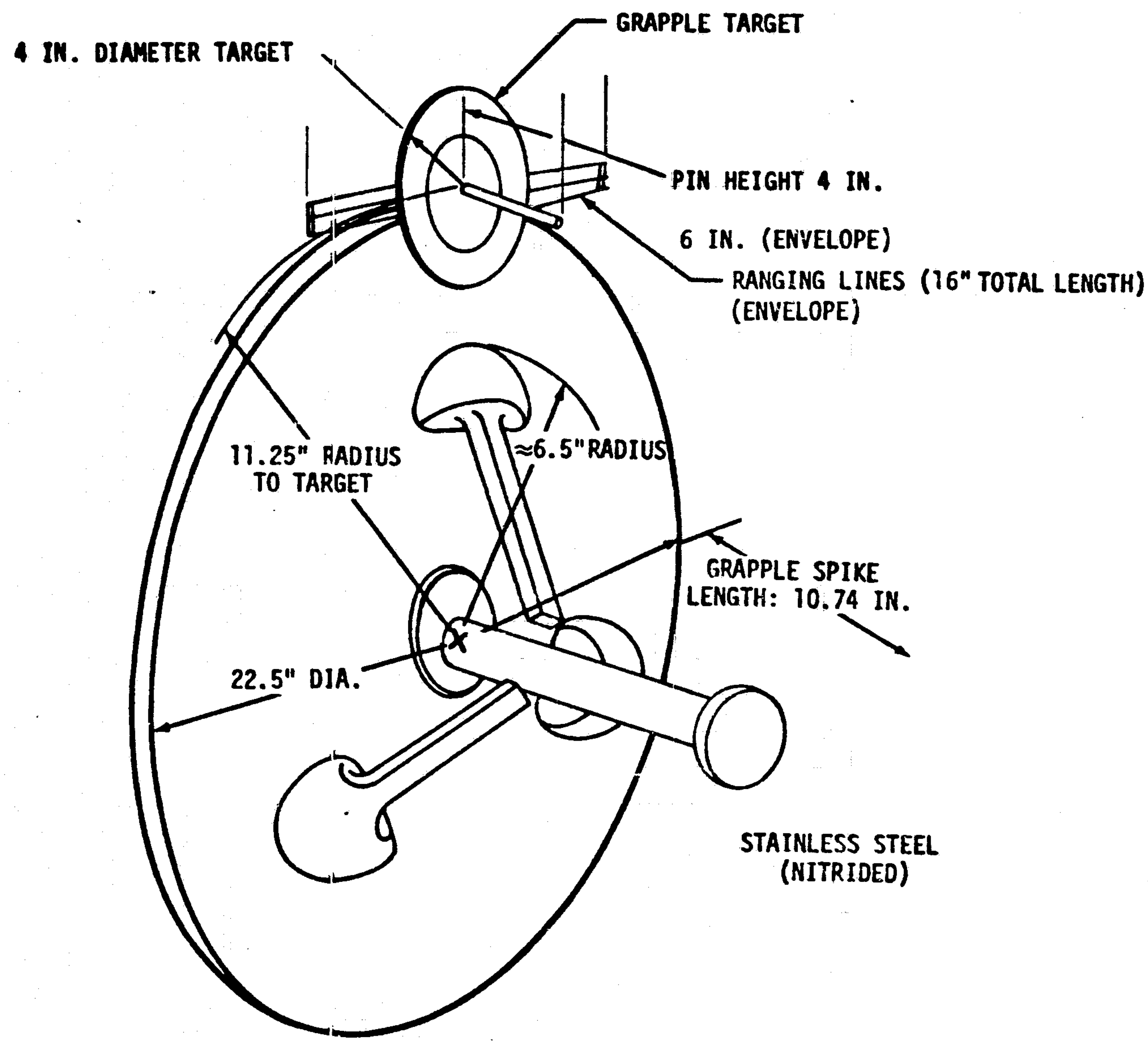

Figure 4.4-13. Standard Grapple Fixture and Target

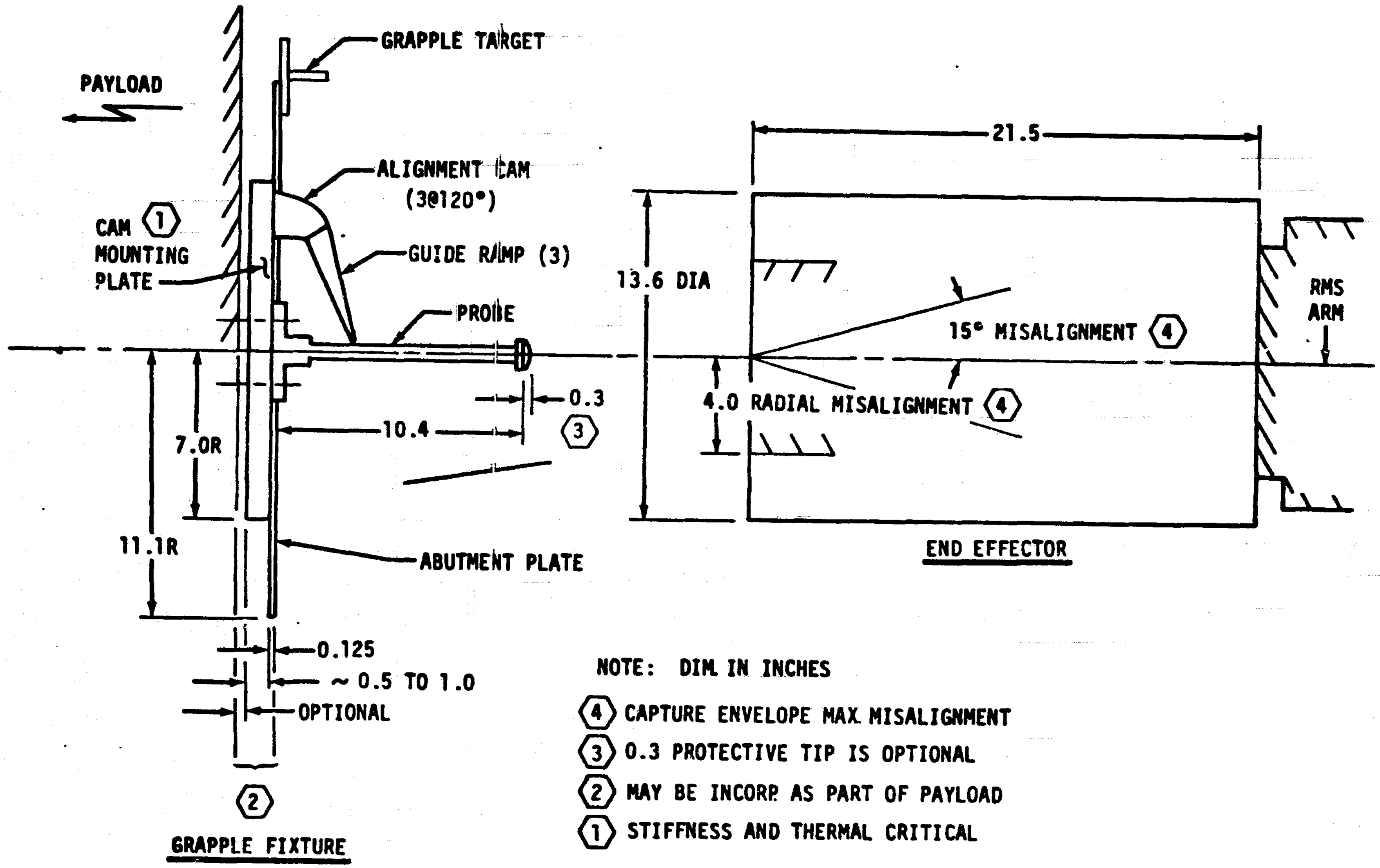

Figure 4.4-14. RMS Standard End Effector and Grapple Fixture Envelope Schematic

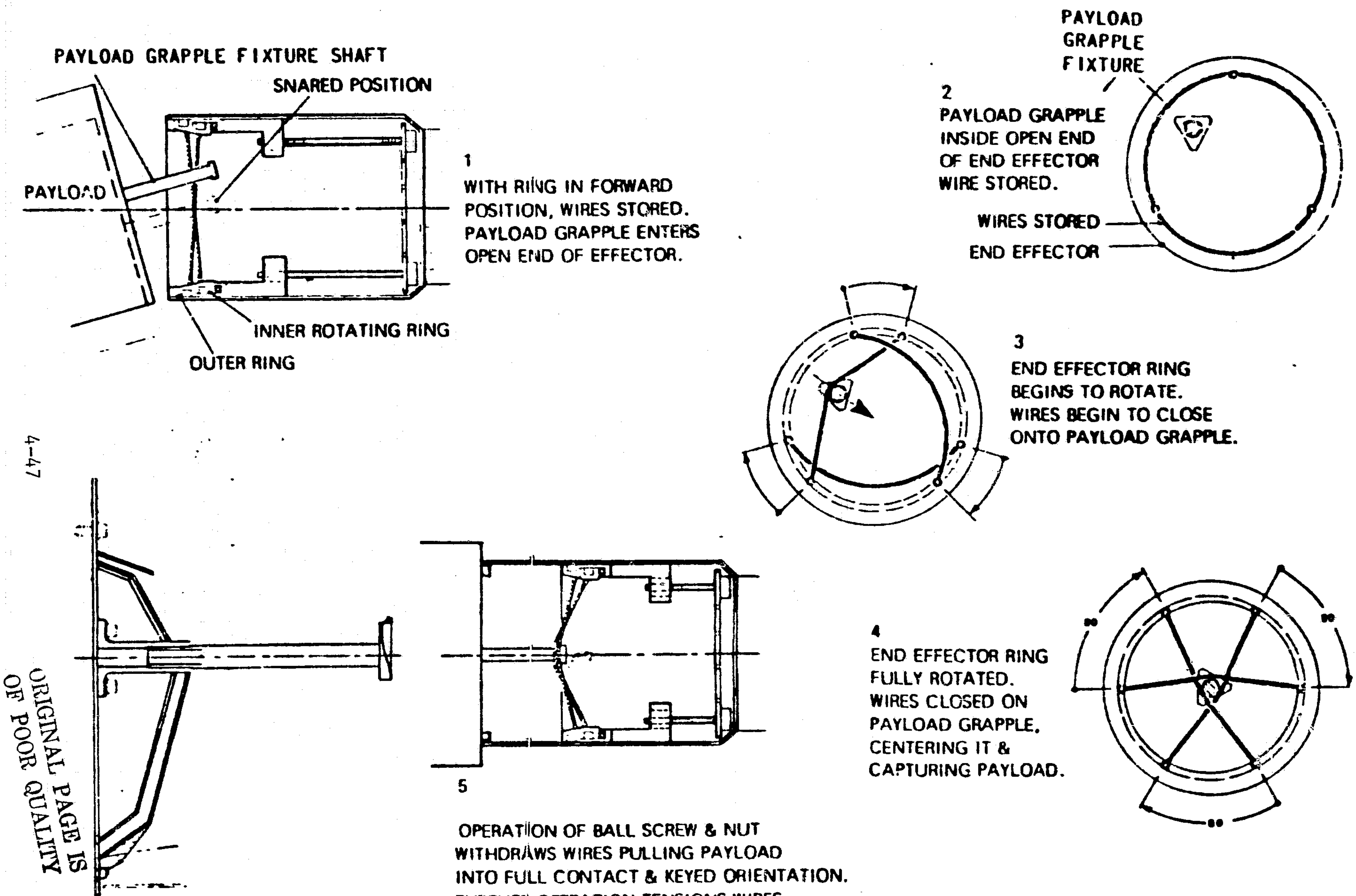

Figure 4.4-15. Snare End Effector, Capture and Rigidize Sequence

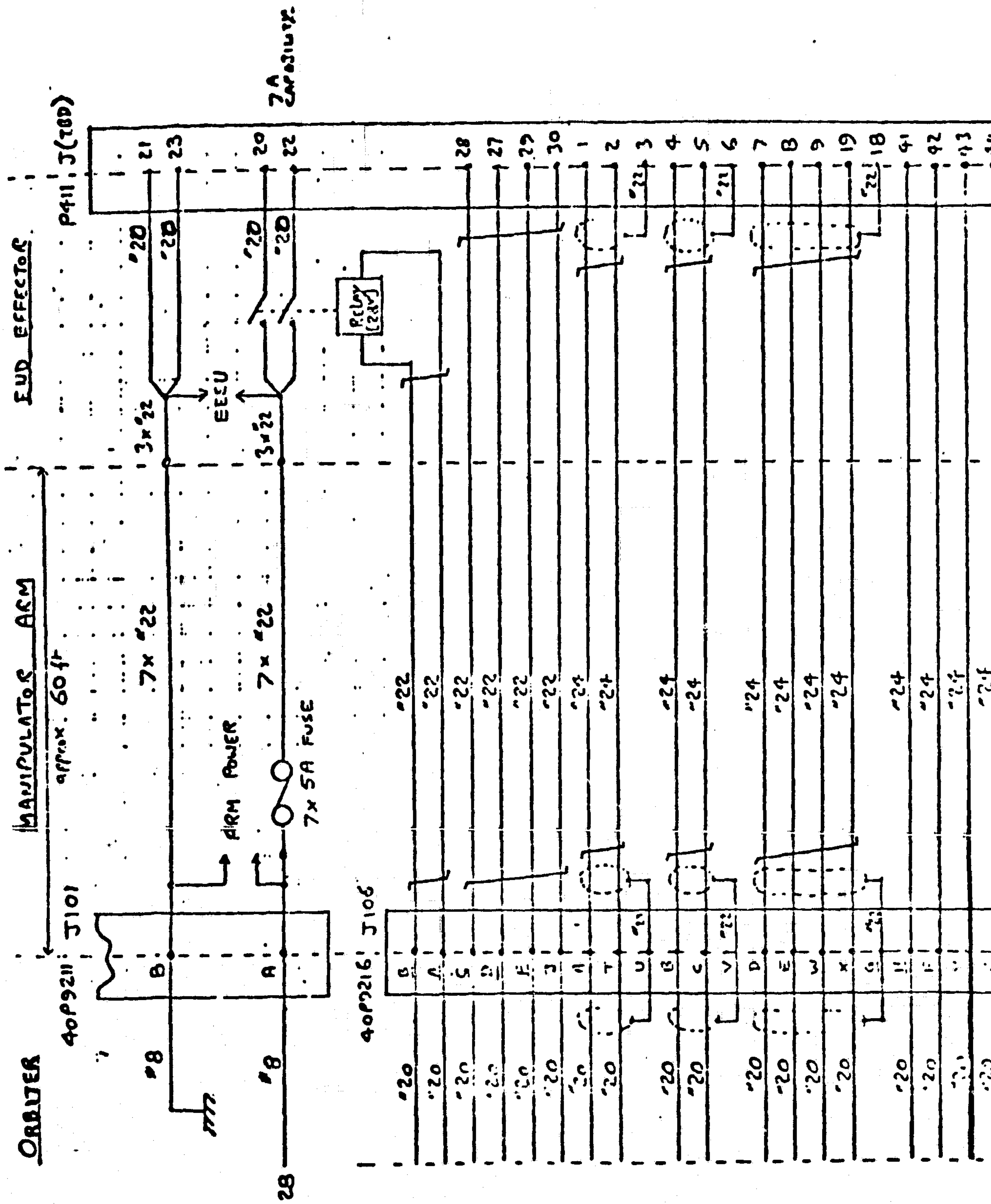

Figure 4.4-16. RMS Standard End Effector/Special-Purpose Electrical End Effector Interface

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A 65,000 lb payload can be released within TBD limits.

In the automatic mode, the RMS is capable of accurately positioning the end effector (loaded or unloaded) within ± 2.0 inches (50.8 mm) and $\pm 1°$ relative to the shoulder attach point. In the manual augmented mode the end effector positioning accuracy is primarily a function of operator visibility.

The manipulator arm will transmit, when fully extended and attached to a payload, loads not exceeding the following:

a. A combined 12-lb shear force and 160 ft-lb bending moment at the end effector.

b. A 230 ft-lb torque about the end effector axis. An example of the forces and torques that are applied by the end effector for various arm configurations are shown in Table 4.4-2.

Table 4.4-2. Force/Torque Capability at End Effector

	Torque Range (ft/lbs) Min	Max	Force (lbs) Min	Max	Condition
Shoulder Yaw	772	1158	15.44	23.2	Straight Arm
Shoulder Pitch	772	1158	15.44	23.2	Straight Arm
Elbow Pitch	528	792	18.41	27.3	Bent Arm Overall Length < 42 Ft.
Wrist Pitch	231	347	37.97	57.0	Bent Arm Overall Length < 20 Ft.
Wrist Yaw	231	347	54.35	81.6	Bent Arm Overall Length < 14 Ft.
Wrist Roll	231	347	-		

NOTE: All values are quotes for the arm under steady-state rigid body static condition; e.g., in payload bay - and single-joint drive.

The manipulator arm is capable of operating (when exposed to direct and/or reflected sunlight) for not less than:

- 30 minutes when operating in the cargo bay
- 120 minutes when operating outside the cargo bay

RMS Control System

Control of the RMS is effected by the operator from the RMS D&C panel in the aft flight deck. The operator has access to four prime control modes, in which he has varying degrees of software support, and a back-up mode which completely bypasses the control and display software. The control modes that can be selected by the operator are as follows:

a. Manual Augmented Mode - The operator issues commands through two 3-DOF hand controllers for commanding resolved rates for the six degrees of freedom of the arm. The rotational controller provides for resolved roll, pitch, and yaw without inducing translation at the point of resolution. The translation controller provides for resolved up/down, left/right, fore/aft translation without inducing rotation.

b. Automatic Mode - The manipulator arm movement can be controlled automatically along a prespecified trajectory. This trajectory is defined by a series of predefined positions and orientations stored in the GPC. The operator can select up to four preprogrammed automatic trajectories from the D&C panel mode select rotary switch. Up to 200 points (total) can be stored for auto trajectories, each point defined by orbiter reference position x, y, z, plus yaw, pitch, roll orientation.

A second type of automatic trajectory can be initiated by the RMS operator through the D&C select switch and the GPC keyboard. This is the operator commanded auto sequence mode and is initiated by input of the required position and orientation of the end effector or payload. A straight line trajectory is then performed from the current position and orientation to the desired position and orientation.

The above automatic sequence capabilities are available to be negotiated by payloads on an individual basis.

c. Single-Joint Drive Mode - The operator commands, through D&C panel switches, movements of individual arm joints. These commands are made through the RMS software, which controls the position of all joints, limits drive speeds, provides joint position displays, and indicates when joint angle reach limits are encountered.

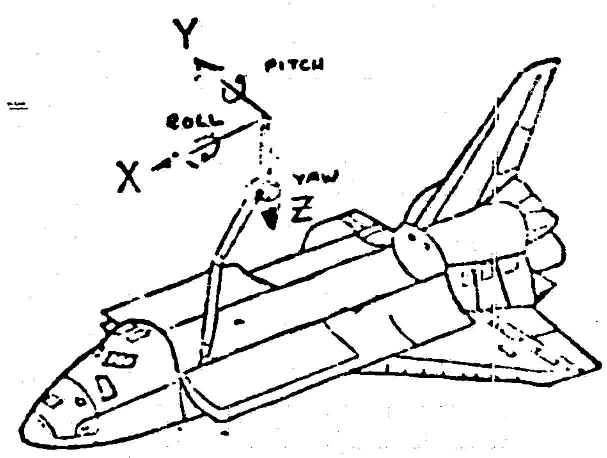
d. Direct-Drive Mode - Direct drive control of the RMS is by the operator command of individual joints, using hardwired commands from the D&C panel. This is a contingency mode which bypasses the software when driving the motors (software data are normally displayed).

e. Back-Up Drive Mode - Back-up control of individual joints by operator commands through unique hardwired channels. No position data are displayed.

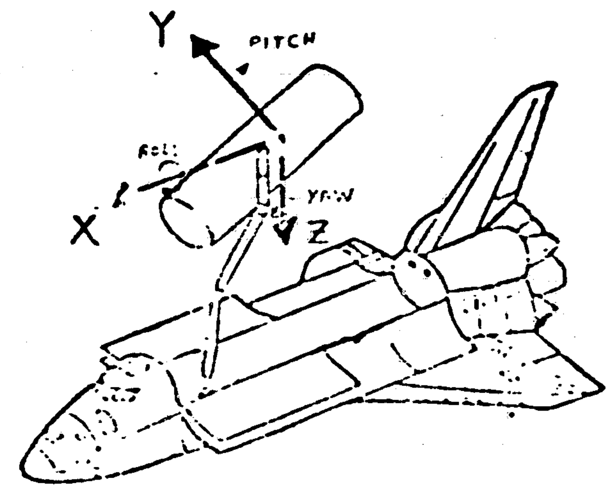
The combined operations of the six joints of the manipulator arm, through one of the appropriate control modes above, enables the operator to move the end effector in six degrees of freedom (3 degrees of motion in translation, 3 in rotation). The coordinate systems relating these travel directions are shown in Fig. 4.4-17. In the manual modes, the operator commands movement of the end effector using the THC and RHC in the selected coordinate system. Operations in the automatic control mode will utilize the orbiter referenced coordinate system.

RMS Software

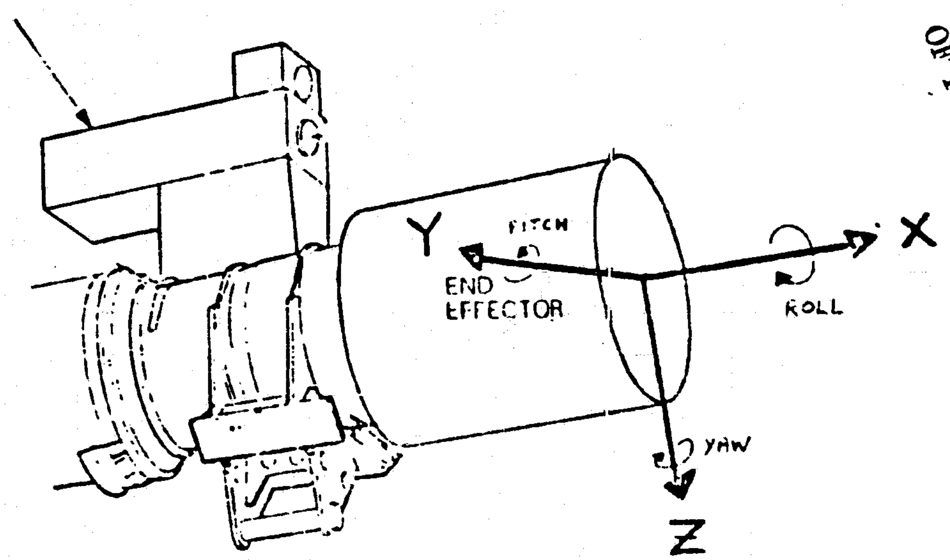
The RMS software, under which most RMS operations are performed, resides in the orbiter general-purpose computer (GPC). The RMS software performs the following functions:



ORBITER UNLOADED. POINT OF RESOLUTION IS TIP OF END EFFECTOR.



ORBITER LOADED. POINT OF RESOLUTION IS MASS OR GEOMETRIC CENTER OF PAYLOAD.



END EFFECTOR. POINT OF RESOLUTION IS TIP OF END EFFECTOR.

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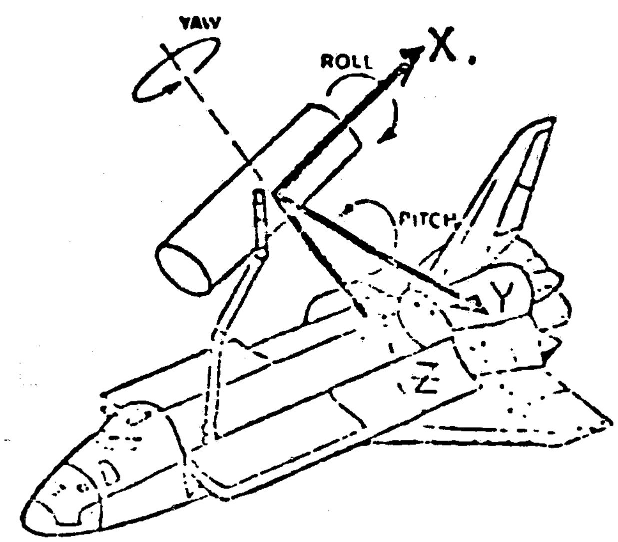

PAYLOAD. POINT OF RESOLUTION IS MASS OR GEOMETRIC CENTER OF THE PAYLOAD.

Figure 4.4-17. Control Coordinate Reference Systems

- Translates operator commands into RMS arm operations and motions.
- Monitors RMS status
- Performs display computational tasks for information to the RMS operator, including caution and warning.

Control algorithms contained in the RMS software convert operator commands (normally input by the hand controllers at the D&C panel) into output rates resolved for each joint of the arm. The rate demands to the joint servos are output within limits defined according to arm and individual joint loading conditions present at the time of computation.

Initialization Data

Parameters with which the RMS software is initialized may vary from flight to flight. These parameters may be RMS hardware dependent (generally called I-loads) or flight and payload dependent (generally called Level C data). The hardware dependent parameters include: (a) end effector length, (b) hand controller biases, and (c) tachometer biases, etc. The flight and payload dependent parameters include the following (nominal values for a 32K payload are indicated:

	Coarse	Vernier
Maximum payload translation rate	0.2 fps	0.01 fps
Maximum payload rotation rate	0.0083 rad/sec	0.00415 rad/sec
Joint angle course rate limits	--	--
Joint angle vernier rate limits	--	--
Payload to end effector transformation matrix		
Automatic trajectory parameters		

The RMS initialization parameters (I-load and Level C) are identified in SD 77-SH-0002A, Level C Functional Subsystem Software Requirements (FSSR) document. Some of these quantities can be changed on ~~orbit through GPS key~~board input. To generate the payload dependent RMS software parameters, payload characteristics should be provided approximately one year prior to flight. These characteristics, and their allowable variations, are as follows:

- Payload mass to $\pm 10\%$
- Payload center of mass to ± 6 inches, defined in Payload Coordinate System
- Moments of inertia about payload principal axes to $\pm 10\%$
- Payload cross-products of inertia, to $\pm 10\%$
- Grapple fixture location(s) and installation orientation, in payload coordinates. If the payload has no preference, NASA will select grapple fixture orientation. The grapple fixture will normally be located within 5% (of payload length) of the Y-Z plane of the payload center of mass.

Downlist Data

A number of RMS parameters are on the GPC downlist. These measurements are signals which are used directly or indirectly to provide data to the flight computers, the RMS operator, the ground mission controllers, or flight planners regarding the systems performance, component status, or condition of hardware and/or software elements. Each measurement is given a unique identification number to identify its signal source or location, sample rate, range, and units. The available RMS downlist parameters are listed in SD 77-SH-0002A, Level C Functional Subsystem Software Requirements (FSSR) document.

Orbiter Crew Station

The orbiter aft flight deck contains the primary stations for payload deployment and retrieval operations. The RMS D&C is located at panel A-9 as shown in Fig. 4.4-18. All RMS D&C, including the hand controllers (but excluding RMS software initialization controls), are located at this port side of the on-orbit station. In addition, CCTV monitors and exterior-viewing windows are located at this RMS operator's station. The starboard side of the on-orbit station contains the displays and controls required for orbiter vehicle translation and attitude control. The mission station will contain the CRT and keyboard utilized to initialize the RMS software and checkout sequences and to provide messages for operator information and action. Two aft windows and two overhead windows are located to provide direct exterior viewing for two operators at the on-orbit station.

Orbiter Exterior Lighting

The orbiter exterior lighting in the vicinity of the cargo bay is described in ICD-2-19001. This lighting is used to provide illumination to aid direct and, at times, indirect (CCTV) viewing of payload handling and proximity operations. In addition to the cargo bay bulkhead and overhead lights, a light is located on the wrist segment of the RMS arm, to provide illumination for grappling or for illumination to areas that may be shadowed by elements within the payload bay. This RMS light, along with a CCTV camera, is fixed-mounted to the rolling member of the RMS wrist joint, as shown in Fig. 4.4-19. The RMS light brightness is 3 ft-candles at 30 feet, diminishing to 0.15 ft-candle at 200 ft.

Closed Circuit Television (CCTV) System

The orbiter CCTV system is described in ICD-2-19001. The orbiter can accommodate up to five CCTV camera locations within the cargo bay. The standard locations are considered to be one of the mirror image positions on the forward and aft bulkheads, plus one of four keel positons. In addition, the RMS can accommodate two camera positions on the manipulator arm; one wrist and one elbow location. The CCTV D&C panel at the aft crew station is used to control all exterior CCTV cameras, including serial operation of the two RMS cameras. CCTV cameras are generally considered as kittable with any mix, up to five cameras, installed to support mission requirements. These installations may include, on occasion, cameras mounted on payload-provided cradles

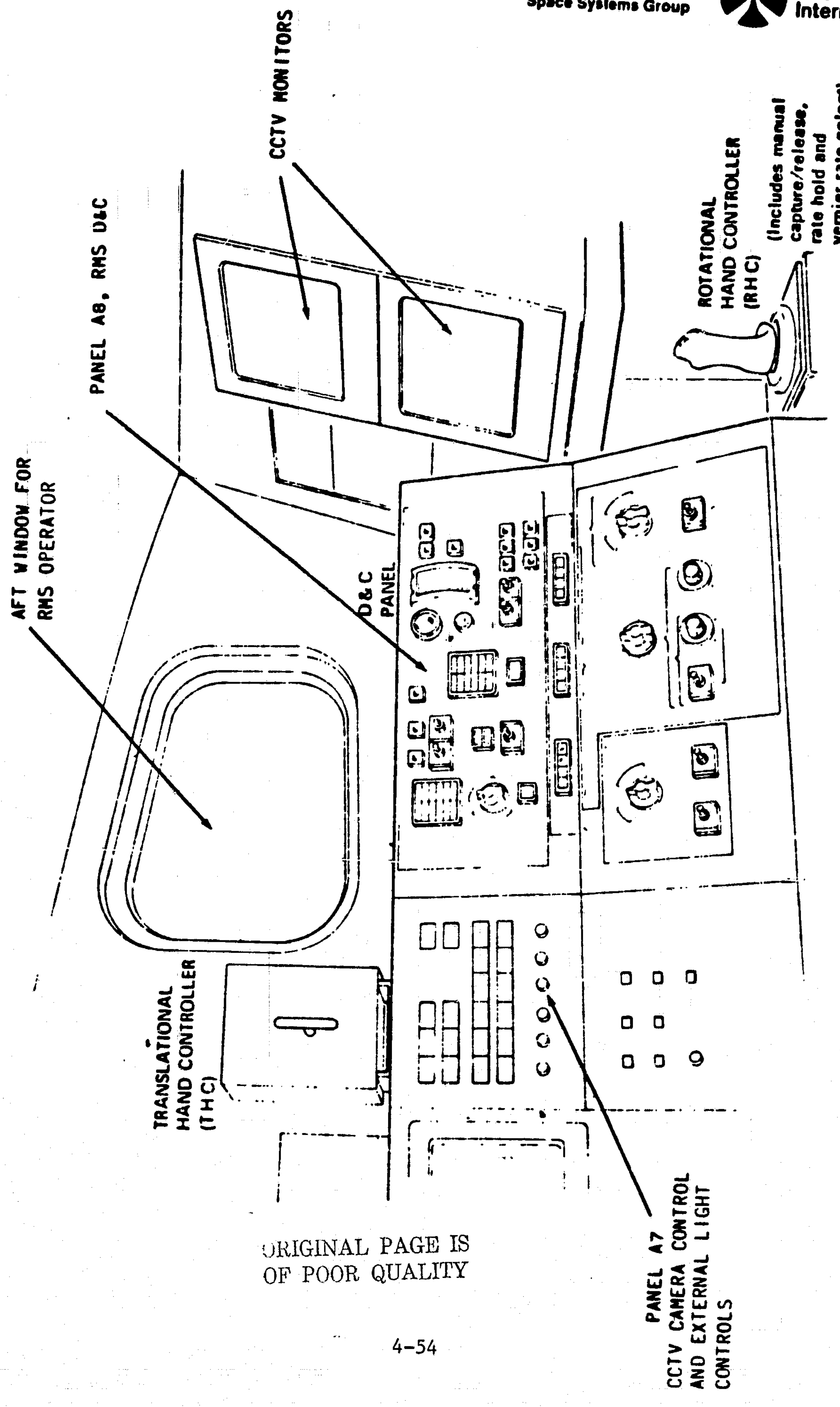

Figure 4.4-18. RMS Operator Station

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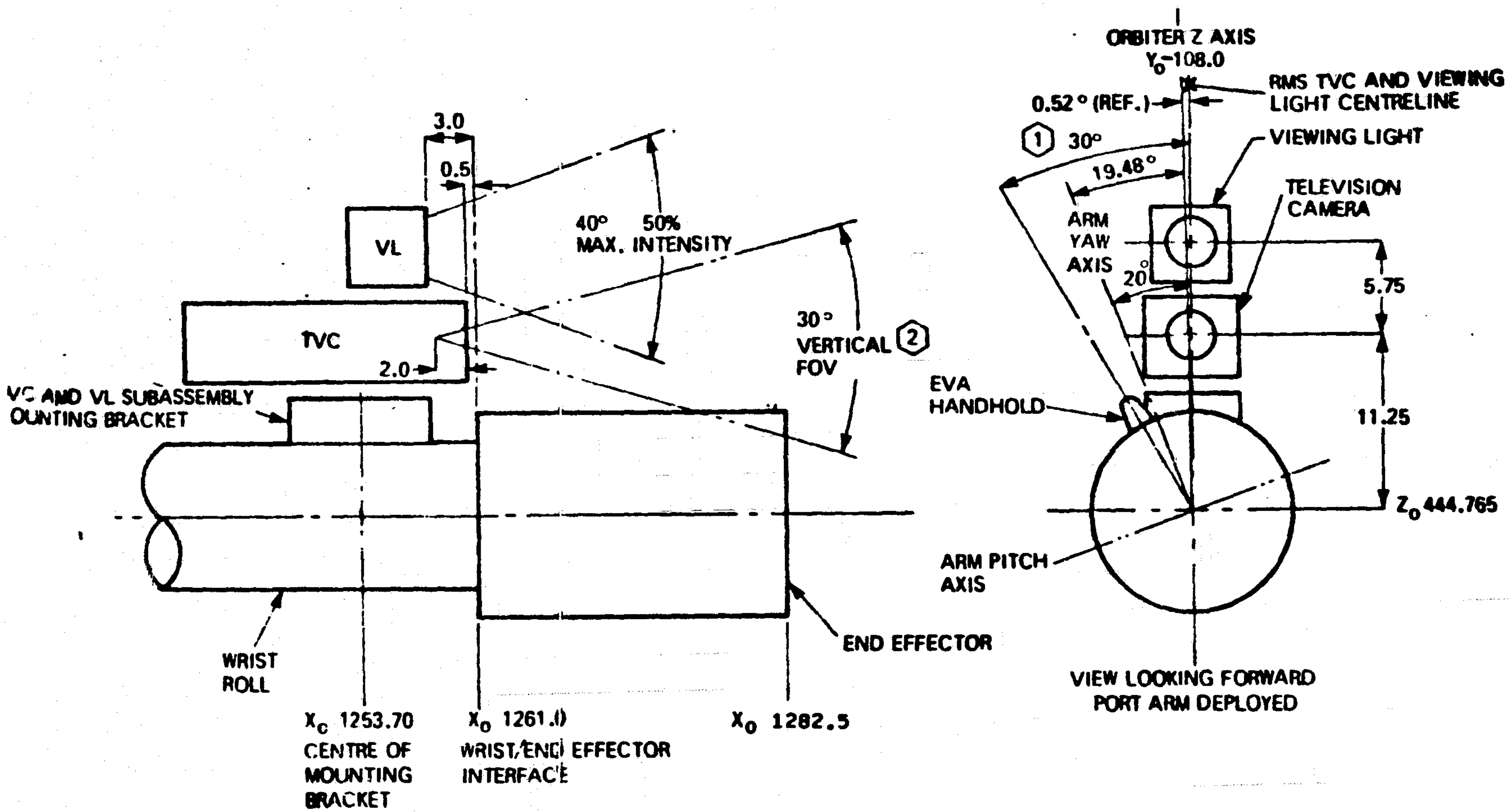

(1) EVA HANDHOLD LOCATION, IDENTICAL FOR PORT AND STARBOARD CONFIGURED M.A.

(2) ASSUMES MAXIMUM 48° DIAGONAL FOV

Figure 4.4-19. RMS CCTV Wrist Camera and Light Subassembly Design Configuration

or hardware (utilizing orbiter junction and wiring capability) to support the viewing requirements for the payload deployment or berthing operations. The CCTV mounting location payload options are indicated in Fig. 4.4-20. All CCTV cameras will haze zoom and iris control. In addition, the forward and aft bulkhead cameras and the optional RMS elbow camera have pan and tilt control, with pan and tilt angles displayed on the CCTV monitors. The TV cameras will be capable of accommodating a range of lenses for special payload applications; the TV lenses may be removed and replaced prior to flight. The field of view for the standard lens varies from approximately 48.0° diagonal, to approximately 8.5° diagonal, when focused at infinity.

4.4.4 Beam Builder

The beam builder is under development by General Dynamics Convair Division. The information on the following pages was taken from "Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS)" final report, Volume II, Study Results, CASD-ASP77-017, dated 5-26-78.

The SCAFE beam builder is an automatic machine process which fabricates beam assemblies from non-metallic materials stored within the machine. The materials are preconsolidated thermoplastic graphite/fiberglass composites which are manufactured in a convenient form for small volume storage. The thermoplastic composite materials not only provide excellent properties for space structures, but lend themselves to automatic fabrication techniques because they are heat formable and can be joined by efficient spot welding techniques.

The beam builder concept satisfies the following design criteria:

- Power utilization well within orbiter capability
- Automatic quality control
- Least amount of material
- Fewest number of beam weld joints
- No growth limitations
- Low weight

Beam Builder Concept

The basic processes of the beam builder are illustrated schematically in Fig. 4.4-21. The beam is constructed of three formed caps, joined to channel-shaped cross-members, and stabilized with six zig-zag plyed tension cord diagonals. Fabrication of this beam requires these processes:

a. Storage. **Flat strip material for the caps and cross-members, and the cord for the diagonals are stored by a process which provides safe, positive containment and dispenses the material with ease.**

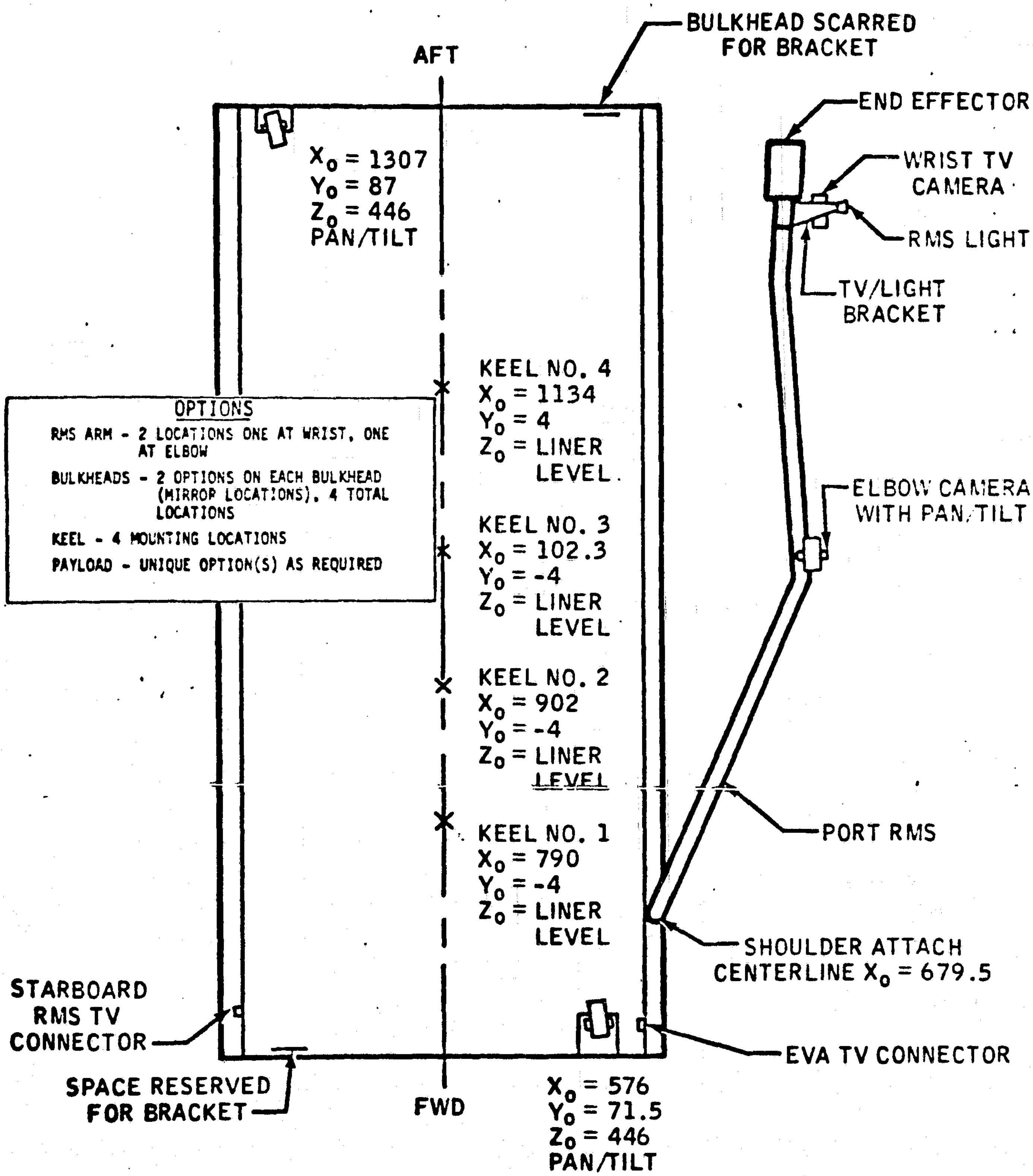

Figure 4.4-20. CCTV Camera Mounting Options

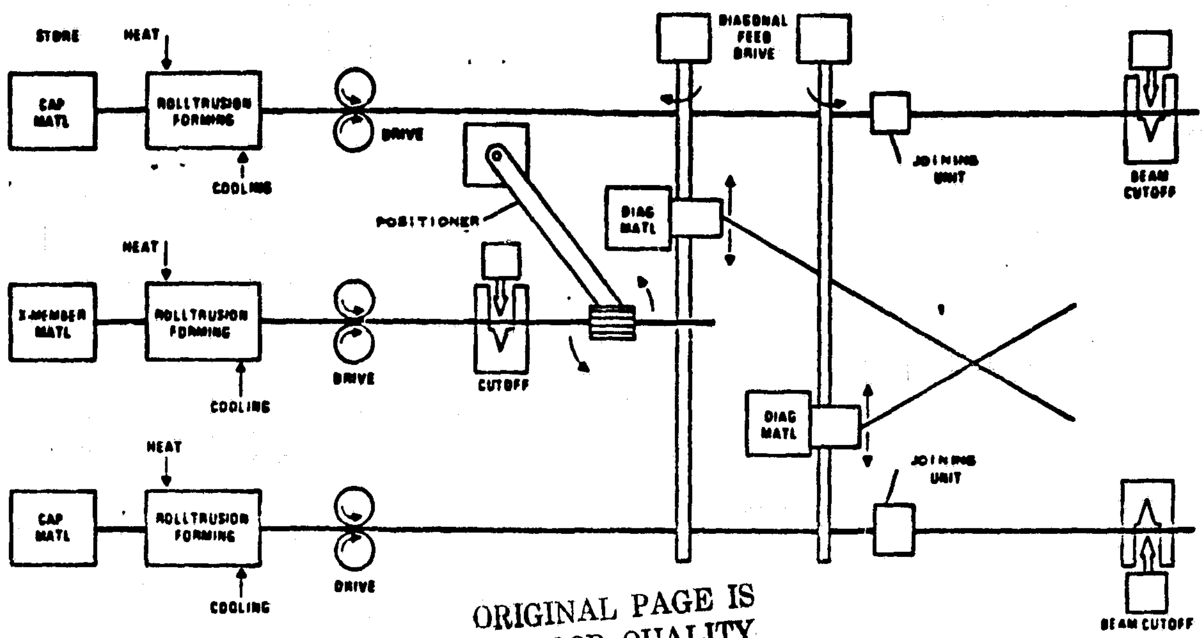

Figure 4.4-21. Cyclic Feed Fabricator Functional Schematic

b. Heating. The flat strip material for the caps and cross-members is fed through a heating section in preparation for forming. The heating section applies heat only to bend zones in order to conserve energy. The bend zones are heated to the plastic state prior to entering the forming section.

c. Forming. The heated caps and cross-members are formed to the desired cross sectional shape by the Convair-developed rolltrusion process.

d. Cooling. On exit from the forming process, the beam members are cooled to a satisfactory use temperature before exposure to load.

e. Drive. The beam is moved through the fabrication process and deployed into space by a drive mechanism on each cap member. The drive mechanism also provides the force necessary to extract the cap and cross-member material from storage and pull it through the forming process.

f. Diagonal Cord Applicator. As the beam advances through the fabrication process, the diagonal cord members are plyed across each face of the beam. The cords are properly tensioned and positioned for joining.

g. Cross-Member Positioner. Before the finished cross-members are cut to length, a positioner grasps the member. After cutoff, the positioners rotate and translate the cross-members into position for joining to the caps.

h. Joining. When the cross-members are positioned and the cords are positioned and tensioned, the joining process permanently joins the beam elements together.

i. Cutoff. Cutoff devices are required to cut cross-members to length and to cut off finished lengths of beam.

The cyclic-feed beam builder operates for a 40-second run period during which the caps and beams are advanced at 2.2 m per minute. After 1.434 m beam extension, a pause of 40 seconds is made for cross-member and diagonal cord attachment. During the pause period, the formed cross-members are grasped by the positioner, cut off, and positioned on the caps. The diagonal cords are aligned between the cap and cross-member by the cord feed mechanisms and the cord and cap are ultrasonic weld joined to the cap. The beam builder then repeats the operating cycle. The configuration of the machine is shown in Figure 4.4-22.

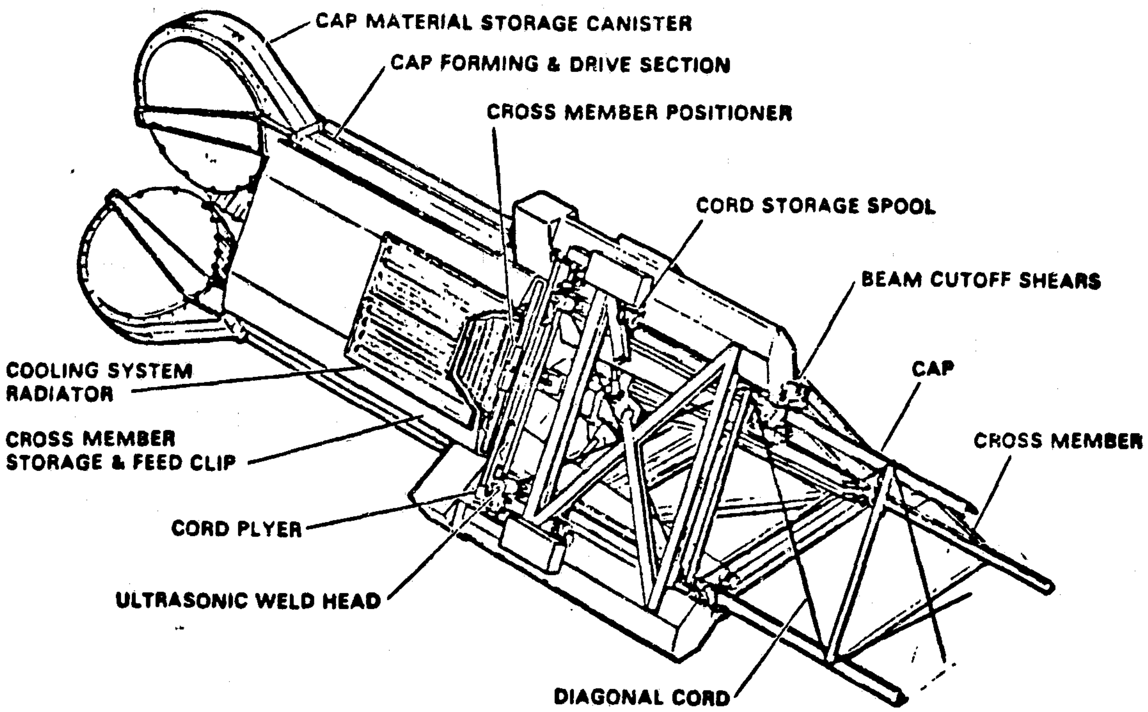

Figure 4.4-22. SCAFEDS Beam Builder Concept

Preliminary Design Description

Preliminary performance data are summarized in Table 4.4-3.

Cap Forming Machine Subsystem

The cap forming machine assembly contains all elements necessary to continuously process flat strip glass/graphite/thermoplastic material into the baseline cap configuration. Approximately 918 m of material is coiled in the roll retained in the storage canister. The roll turns freely on bearing-mounted rollers and unwinds uniformly as material is used. The canister is in two halves, with one half hinged to permit the material roll to be inserted. When the canister is closed and latched, an access panel in the hinged half is opened to allow the material to be manually routed over the heating section guide rollers into the forming section manual feed rollers.

Table 4.4-3. Beam Builder Preliminary Design and Performance Data

PROCESS OR SUBSYSTEM	PARAMETER	LIMITS OR TOLERANCE
Material Storage	Roll O.D.	121.4 cm Max
	Roll I.D.	60 cm Min
	Roll Length	918.2 m
	Roll Width	19.05 cm
	Roll Weight	262.2 kg
Heating	Temperature Limits:	
	1st Stage	482°K
	2nd Stage	707°K
	Forming Section	707°K
	Start-Up Time	430 seconds
Forming	Forming Section Length	
	Max. Forming Rate	Not Determined
Cooling	Actuation Time	0.2 seconds
	Actuator Stroke	0.32 cm
	Max. Cooling Time	12 seconds
Drive	Cap Stroke Tolerance	± TBD
	Cap Speed	3.585 cm/sec
	Max. Acceleration	1.3 cm/sec^2
	Max. Force Capability	533N
	Max. Force Required	311N
	Run Time	40 seconds
	Pause Time	40 seconds
Cord Storage	Cord on Spool:	
	Length	1219 m
	O.D.	13.12 cm
	I.D.	7.62 cm
	Width	13.12 cm
	Weight per Spool	2.13 kg
	Spool Drag Torque	56.5 ± 5.6 N-cm
Cord Tensioner	Tensioning Force	44.5 ± 8.9 N
	Spring Stroke	21.2 cm
	Spring Load Rating	89 N
	Max. Cord Speed	11.3 cm/sec
	Pulley Diameter	7.1 cm
Cord Plyer	Travel Speed	10.7 cm/sec
	Pulley Diameter	7.1 cm

Table 4.4-3. Beam Builder Preliminary Design and Performance Data (Cont.)

PROCESS OR SUBSYSTEM	PARAMETER	LIMITS OR TOLERANCE
Clip Storage and Feed	Capacity	650 pieces
	Weight of Cross-Members	79.8 kg
	Feed Rate	0.4 cm/sec
Cross-Member Positioner	Time to Position Cross-Member	3 sec
	Separation Time	1 sec
	Return Time	4 sec
Welding Mechanism	Stroke	4 cm
	Time to Engage and Pierce	3 sec
	Time to Engage for Weld	0.2 sec
	Weld Time	2 sec
	Cooling Time	1 sec
	Retraction Time	3 sec
Cutoff Mechanism	Time to Engage and Shear	1 sec
	Time to Retract	1 sec

The heating section is partially built into the storage canister with resistance strip heaters and parabolic reflectors mounted on the access panel. The heating section extends from the access panel up to the point where the material starts to form.

The material passes from the heating section through the forming section. The rolltrusion forming section is also equipped with strip heaters which heat the partially formed material in preparation for start-up of the machine.

The material then passes from the forming section into the cooling section where it is contact cooled by aluminum platens. Cooling fluid is supplied to the inside cooling platens and expelled as waste heat by an independent cooling system in the beam builder. Waste heat is also extracted from the heater reflectors by the cooling fluid loop. The cooling platens cool one bay length of cap section during the 40-second pause period.

The drive section has four friction-drive rollers which provide the necessary pull force on the cap to draw the material from the storage roll through the heat/form/cool sections. The three cap drive sections also provide the push force to advance the beam out of the beam builder.

Cross-Member Subsystem

The cross-member clip is constructed of machined aluminum sections. Two mating center support panels are joined by two end piece assemblies to form the basic clip structure.

The stack of cross-members is supported and fed to the beam assembly process by four timing belts. The clips are indexed on the belts by serations on the mating surfaces of the belts. The belt drive and belt pulleys are mounted on the center support panels. The clip holds 650 cross-members.

The clip is loaded and assembled by laying the stack of cross-members on one of the center support/belt drive subassemblies. The second center support/belt drive subassembly is then layed on the stack and all belts inspected for proper mesh with the cross-members. The end pieces, which consist of two mated halves, are bolted to the center supports.

The feed drive is a redundant motor drive which provides simultaneous output to all four feed belts. The retainer mechanisms at the output end of the clip are described below.

Mounting pads on the inboard center support allow the clip assembly to be bolted to the beam builder structure.

The cross-member positioner/handler mechanism transports one cross-member at a time from the storage clip to the installation position on the beam. During the run period, when the beam is advancing one bay length, the positioner/handler is fully retracted with the handler below the plane of the beam side. This allows the last cross-member installed to clear the handler and also allows the cord plyers to pass over the handler/positioner.

At ~~some time after the cord plyers have completed their stroke,~~ each position arm is rotated and translated into position for receiving the next cross-member from the clip. The cross-member retainers on each end of the next cross-member are retracted and the clip drive stepper motors are activated. When the stack has moved about 0.4 cm, a sensor in the cross-member handler is triggered. This causes the clip drive motors to stop and cross-member retainers to engage and retain the next to last cross-member. The fingers on the handler also close and grasp the next cross-member to be installed.

The cross-member positioner arm is rotated and translated to remove the cross-member from the clip and lay it in proper position for welding to the cap members. After welding is complete, but before the beam is advanced, the handler fingers are opened and the positioner arm rotated to drop the handler below the plane of the beam side.

Diagonal Cord Applicator Subsystem

The cord plyer mechanism consists of six reciprocating cord plyer subassemblies. Each plyer is driven along a guide beam by a motor-driven ball reverser lead screw. Each guide beam is equipped with position sensors to monitor the six positions of each cord plyer. Cord is supplied to each plyer from a storage spool over a series of pulleys. The inboard pulleys on the cord plyers are mounted on swivels to allow the cord to be properly aligned as the cord plyer changes position.

Forward and aft cord plyers permit the two cords on each side of the beam to be applied without interference between the moving plyers. The aft cord plyers have a longer stroke than the forward cord plyers because they are set back 13.5 cm from the forward cord plyers. This requires more lateral motion to achieve the required angle between the cord and the caps.

The forward cord plyer must always complete its stroke to the outboard position ahead of the aft cord plyer to avoid a collision with the cord of the aft plyer at the apex of the beam. Similarly, the aft cord plyer must always move from the outboard position first.

The forward and aft cord plyers each have redundant motor drives. Two of the three lead screws are motor driven while the third is driven at either end by a flexible drive shaft. Should one of the two drives fail, the other would drive all three lead screws. The cord plyers are all driven at an average velocity of 10.7 cm/sec.

The cord tensioner mechanism operates in two modes. The first mode is the supply mode where cord passes freely from the storage spool to the cord plyers. The second mode is the tensioning mode whereby the free-turning capstan is stopped and held by an electric-operated clutch brake. This causes the traveling pulley to extend under the force applied by the constant-force spring. A tension force equal to one-half the spring force is thus applied to the cord. Total ~~spring force is measured by a force transducer~~ attached to a guide pulley.

A cord tension force of 44.5 ± 8.9 N is applied to each cord during assembly. This preloads the cords sufficiently to preclude any slackening or over tensioning due to thermal and deflection effects. The ±8.9 N variation limits the theoretical twist and deflection in the beam to less than 1.2° of twist and 0.5 cm of tip deflection for a 200 m beam.

The stroke of the traveling pulley assures that a constant force is maintained on the cord throughout the assembly sequent. As the cord plyers move from the outboard position to the ready-to-weld position, the traveling pulley automatically compensates for the change in cord length.

As the beam starts to advance in the beam builder, the cord tensioners are in the free feed mode and the forward cord plyer drive is activated. A 3-second delay is provided before start of the aft cord plyer drive so that the forward cord plyers reach their outboard position first.

The cord plyers stop at their outboard positions and, after 23 seconds, the cord tensioner capstan brakes are applied. The beam drive thus applies the necessary force to extend the cord tensioner constant force springs to the proper stroke.

After the beam is stopped and the cross-members to be attached are in position, the ultrasonic welding heads are advanced and activated momentarily to allow a pin on each weld head to pierce the cross-member and cap just below each cord. When the piercing is completed, the aft cord plyer drive is activated. A 2-second delay permits the aft cord plyer cords to move clear of the forward cord plyers before the forward plyers start to move. The forward and aft cord plyers move to the ready-to-weld position while the cord tension is maintained by the cord tensioning mechanism.

At the ready-to-weld position, the cords have been strung over the piercing pins and are at their final assembled angle to the beam caps. At the conclusion of the welding operation, the cord tensioner capstan brakes are released and the next cycle is ready to begin.

Beam Welding Subsystem

The beam welding mechanism has six ultrasonic weld head assemblies which are driven in pairs by a redundant motor drive for each pair. The three weld head positions are: (1) fully retracted to allow the cross-members to be positioned by the cross-member positioners; (2) pierce position, where the piercing pin on each weld horn has penetrated the cross-member and cap; and (3) the weld position, where the weld horn is engaged and properly loaded to enable the welds to be accomplished.

Each weld horn is equipped to perform two dimple spot welds and one special cord capturing weld simultaneously. The weld hornsact against internal anvils, which are extended against the inside surface of the caps by a common dual motor-driven cam mechanism. The weld station is supported and sized by the combined action of the weld anvils and the beam support rollers located on the centerline of the weld station. A spring cartridge on each anvil actuator-rod limits the engagement force. The weld anvils are retracted to allow the weld dimples to pass and to minimize friction drag on the caps.

Beam Support Subsystem

The beam is supported at two stations by precision located metal rollers. The roller support stations fall on the centerline of the beam cross-members when the beam builder is in the assembly pause mode. The rollers maintain beam straightness during assembly and react bending moments during beam extension.

Coolant Subsystem

The coolant (F-21 or equivalent) is circulated through the cooling platens and heater reflectors in the heating and forming sections of the three cap forming machines. The coolant removes an estimated 448 watts total from the platens and reflectors. The high temperature coolant then flows through the radiator panel where the excess heat is radiated to space. The radiating area is sized to reject the 448 watts cooling load under maximum solar heat influx conditions. The silver backed teflon tape provides high emittance and low absorptance to minimize the thermal impact of solar heating.

The pump operates with a power demand of 58 watts. Overall system weight is estimated to be 15.3 kg.

The radiator for this system is mounted to one of the clip housings. The remaining components are installed inside the beam builder structure beneath the clips.

Beam Cutoff Subsystem

The beam cutoff mechanism shears each cap and cord member to separate a complete beam from the beam builder. The clamping device is normally retracted to allow the cross-members to travel past the outer clamps.

In preparation for beam cutoff, a short cutoff bay (60 cm) is manufactured by the beam builder. The cords are layed along the caps within this short bay rather than crossing over in diagonal directions as they do in normal bay construction. The short bay is advanced to the point where the cutoff shears are in the center of the short bay as the next complete bay is in assembly. When the next bay is assembled, the beam builder sequence is interrupted to permit beam cutoff and beam builder or platform repositioning.

Dual motor drives operate each cutter. As the actuators are extended, the clamps engage the internal backup mechanism and force the backups into position. The shear blades are spring loaded to allow the clamps to fully engage before the shear blades penetrate the cap. The shear blades are then driven through the caps as the actuators continue to extend. This also shears the cords as they lay along the sides of the cap.

Beam Builder Structural Subsystem

The beam builder structure is composed of welded aluminum elements. A preliminary analysis indicates a weight of 660 kg for the complete assembly.

The structure consists of three major segments: a forming section support, a central "spider", and an assembly section support. The forming section support is a trussed hexagonal system whose external surfaces provide support for the three machine storage/forming sections and the three cross-member storage clips. To maintain precise alignment of machine elements, local pads, machined after weld completion are provided at machine/structure interfaces.

The central spider is a three-legged box structure providing a transition load path from the internal forming section support to the external portions of the assembly section supports. It also provides an interface with the beam builder roll/turn positioning mechanism as well as supporting three cantilevered internal support beams and a support pedestal for the cross-member handler and weld anvil actuators.

The three external beams in the assembly section support provide mounting for the cord plyer/tensioner mechanisms, the ultrasonic weld station, the cutoff mechanism, and guiderollers at the weld and exit stations. One of these three beams also supports the beam builder/assembly jig latch system. As a consequence of this eccentric support, the three beams are connected by a cross-bracing system to provide system torsional rigidity, particularly needed in view of the reduced beam section, near the spider attachment plane, to accommodate cord plyer installation.

Beam Builder Support Subsystem

The support subsystem includes the mechanisms and controls which support the beam builder during platform fabrication.

A handling arm assembly attaches to the spider section of the beam builder structure. The handling arm is connected to a mechanism on the assembly jig which positions the beam builder.

A longitudinal beam latch mechanism aligns and couples the beam builder with the assembly jig. It provides the added support necessary to prevent relative motion between the beam builder and assembly jig during longitudinal beam fabrication. A cross-beam latch mechanism is also required to align and support the beam builder during cross-beam fabrication.

4.5 GROUND SUPPORT

The ground support activity is influenced by the concept of utilizing a dedicated orbiter as a construction facility. This orbiter will be outfitted with the appropriate number of electrical energy kits, addition of oxygen and nitrogen tanks required for the EVA operations, special software and controls, and the berthing platform. Therefore, during the turnaround operations, only the replenishing of the expendables will be required. Updating of the software to be compatible with the particular missions may also be required. Unique flight support cradles and support structures will need to be installed for each of the three missions. Appropriate bridge fittings will accommodate the unique flight support equipment. Rapid turnaround between missions is desirable. However, a six-month contingency has been provided in the untended platform mode to account for any ground operations anomalies. The packaging of materials to facilitate rapid turnaround has been considered in such items as the bracing struts' canister and the development of the SCM into a single modular item.

A facility similar to the Operations and Checkout (O&C) building used by Spacelab is anticipated. While there will be no functional interfaces between cargo elements, the physical integration effort is still a time-consuming operation. This effort can be minimized by establishing a dedicated "staging" area where the individual items of the cargo can be accumulated, checked out, and packaged onto their individual flight support elements. The lack of cargo/orbiter functional interfaces eliminates the need for any orbiter functional simulator. Thus, the ground support equipment needs only to include a simple physical simulation of the orbiter cargo bay and all necessary slings, strong-backs, cranes, etc., to handle the cargo elements. All preparation of the cargo elements. All preparation of the cargo will be performed "off line" and thus not impact the standard ground turnaround time for the orbiter. The facility will include the capability to install the various cargo elements onto the standard cargo cradle for transportation to the orbiter for transfer to the payload bay in the horizontal position at the Orbiter Processing Facility (OPF).

4.6 REFERENCES

4-1 NASA
Space Shuttle System Payload Accommodations, JSC 07700, Volume XIV, Revision F, National Aeronautics and Space Administration, L. B. Johnson Space Center, Texas, 22 September 1978

4-2 Rockwell International
Space Construction System Analysis Study
Task 2 Final Report - Systems Analysis of Space Construction, SSD 79-0123, Satellite Systems Division, Rockwell International, June 1979

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5.0 FIRST CONSTRUCTION MISSION

This section describes the detailed integration of the activities for the first construction mission, the analyses performed and results pertaining to this integrated presentation.

5.1 CONSTRUCTION PLAN

The general objective for the first mission plan was to perform as much as possible of the actual fabrication of beams in space and to assemble these into a basic structural framework, together with the electrical wiring connectors and attachment port/end fittings which would facilitate later installations of systems and payloads. Initially, it was not clear that all of this could be accomplished during the first mission due to potential volume limitations of the orbiter payload bay packaging. However, later analysis and design refinement gave assurance that it could all be finished except for the bracing struts provided to support the ends of cross beams during transfer to geosynchronous orbit.

Figure 5.1-1 shows the planned configuration of the platform at the end of the first mission.

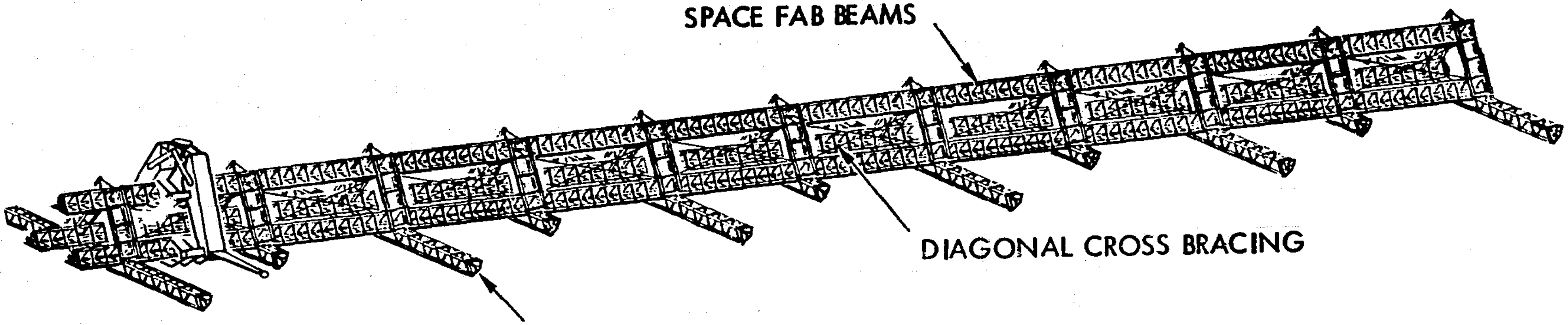
5.1.1 Construction Requirements

The general concepts of construction requirements in Section 2.0 were translated into detailed construction requirements for the first mission. As noted above, the scope of the first mission involves construction of the basic structure (except certain bracing struts) installation of basic wiring, connectors, and attachment ports. In addition, there is a requirement to provide sufficient instrumentation, libration damping, communications and control systems to facilitate rendezvous and berthing to the construction fixture on the second mission. These functions also require an on-board power system (powerlines, batteries, and controls). Such active spacecraft functions are provided in the construction fixture erected during the first mission.

Secondary level requirements include establishing that the basic structure is within acceptable tolerances for straightness and twist, and the recording of observable structural deviations for future reference in payload installations. Additional detail requirements are listed in Table 5.1-1.

5.1.2 Construction Logic

An early step in the construction integration effort was to develop a logic diagram which outlined the major steps and flow of key events of construction, based upon analysis of the baseline design concept. Preliminary design of the platform and activity analyses then proceeded in roughly parallel time periods, considering interactions with the construction process up to the completion of the first mission. The logic diagram was revised



- ELECTRICAL LINES
- INTERFACE CONNECTORS

Figure 5.1-1. Planned Configuration of ETVP at End of First Construction Mission

Table 5.1-1. Detail Construction Requirements for First Mission

REQUIREMENTS	RATIONALE
• All construction power shall be provided by the orbiter and limited to that of a normal payload: up to 7 kW continuously and up to 12 kW for 15 minutes every three hours.	• Volume XIV requirements and cost avoidance for special power supplies.
• The construction shall be performed with the orbiter in a free-drift mode to the maximum degree possible.	• Minimize costs of construction, weight penalties to platform structure and possible delays due to reorientation firings.
• Construction activities shall be performed in parallel to the maximum degree feasible, within power demand limits and crew workload limits.	• Minimize daily on-orbit costs.
• Construction activities shall be automated except where special dexterity, on-site observation or inordinate development costs make EVA desirable.	• Minimize costs due to extending the mission and provide minimal risk to crew.

from time to time as required to reflect new insights developed during the analyses. Figure 5.1-2 shows the final form of the logic diagram for the first mission.

Note that the logic diagram is not a complete end-to-end activity sequence. It does represent the initial buildup of construction fixtures and the unique processes of fabricating the three longitudinal beams. However, at step 9.1 there is a break in the pictured sequence. This point on the chart begins a typical cycle of fabrication and installation of long and short cross beams, together with their associated transverse beams and the cross-brace cords between them. Cycles of repetition are indicated. At the end of the diagram there is a small number of shutdown activities. (The format of Figure 5.1-2 is thus more representative of typical concerns than a complete summary of all the construction activity). Further explanation and illustrations of the construction process are presented in Section 5.2.

In the format of the logic diagram, activities which potentially could be performed roughly in parallel are shown in a column, one above the other: The first time a particular type or unique activity occurs it is designated with a sequence number. Where activities are shown in parallel the numbering system uses a decimal system beginning at (.1) to designate the group of simultaneously occurring functions. Other, single, activities are shown with only the zero after the decimal in the sequence number. Repetitions are not given a sequence number. This system of numbering is admittedly somewhat rough and subjective. For example, transportation of cross and transverse beams is generally the same, being performed by the RMS. However, the reach

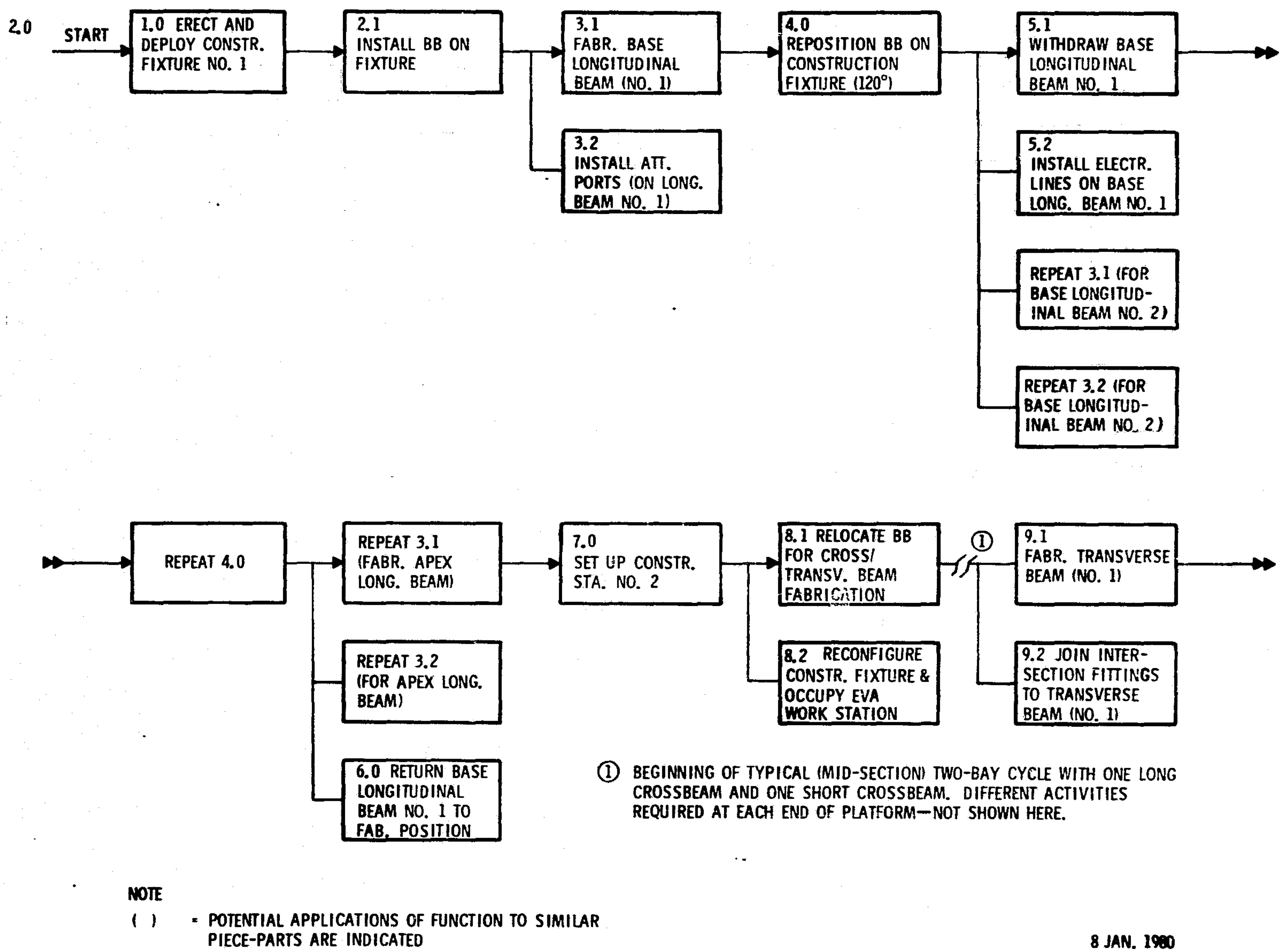


Figure 5.1-2. Engineering and Technology Verification Platform Construction Logic—First Mission

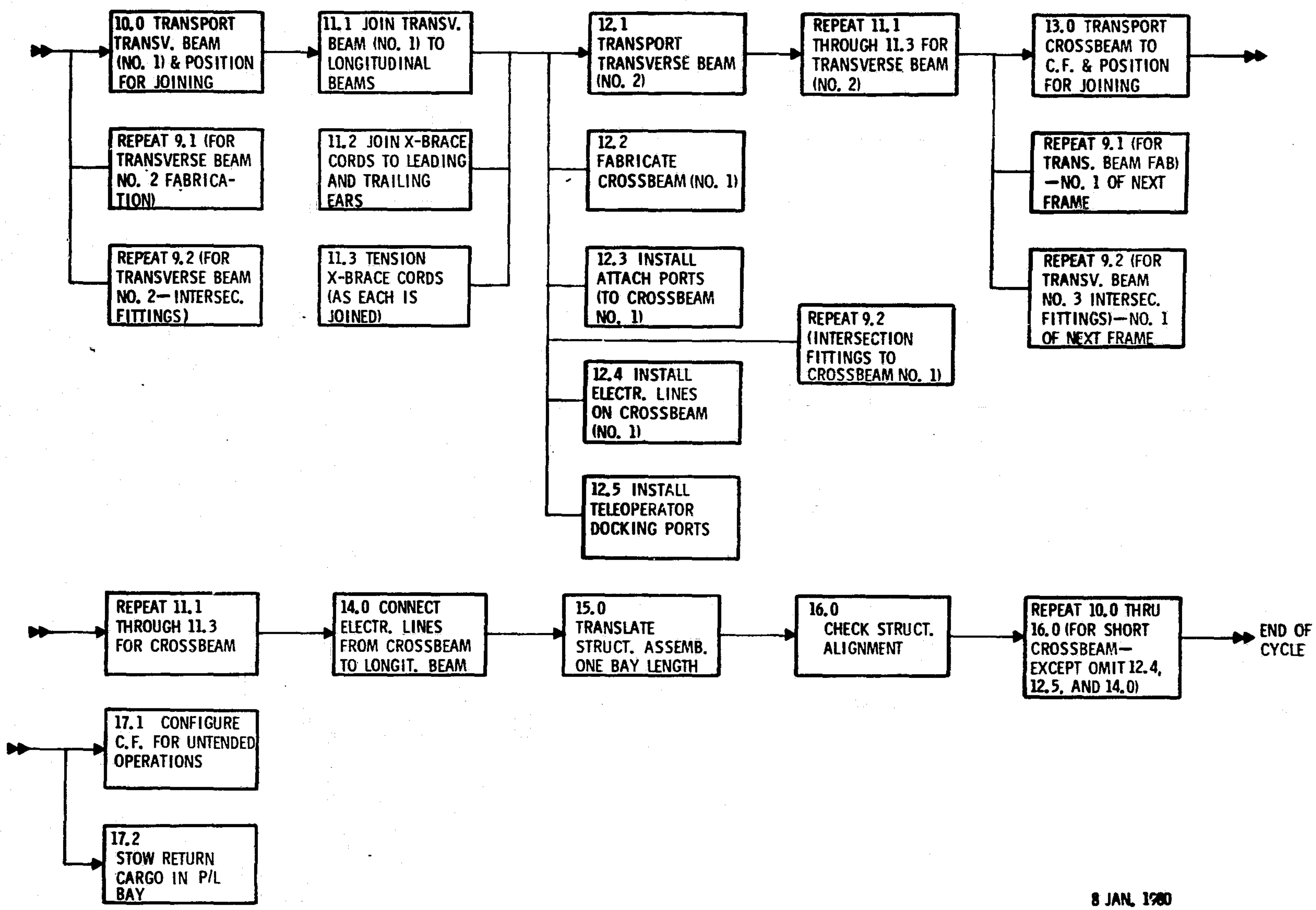


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Figure 5.1-2. Engineering and Technology Verification Platform Construction Logic—First Mission (Cont.)

and manipulation functions are significantly different due to their geometrical orientation distances from the site of pickup and obstructions which must be avoided. As a result, somewhat different durations are required and a separate activity description sheet was prepared for each type.

On the other hand, the installation of intersection fittings to cross beams or transverse beams is considered as a repetition of activity, even though there are some differences in sequence due to the length of beams and distance of the beam builder to the installation point. Also, the construction of cross beams was considered a repetition, but there are both long and short cross beams, with necessarily different requirements for power and duration of fabrication activity.

Another point of interest to the analyst is the separation of certain functions, which in some cases are obviously performed in parallel during the same time period. At the time of beginning the analysis it was not clear which functions could be combined. As the effort proceeded, it was felt useful to maintain a separate identity for many of these functions to avoid inordinate efforts in renumbering the sequences and redefining activities. Where of obvious advantage, two or more functions were combined for analysis into one Construction Activity Data Sheet (these sheets are described in the following Section 5.3).

5.2 CONSTRUCTION PROCESS

The overall process of space construction during the first mission (outlined in the foregoing Section 5.1.2) is further explained and illustrated in this section. In addition, key issues and trades performed during the systems analysis are highlighted.

For purposes of this discussion, the construction process begins after arrival at orbital altitude, opening of payload bay doors and preparation of the orbiter systems for orbital operations. This includes checkout and deployment of the Remote Manipulator System (RMS) to a "ready" position. Figure 5.2-1 illustrates this initial condition, with all cargo still stowed in the payload bay.

The initial effort is to grasp the stowed construction fixture with the RMS standard end effector, rotate and translate it to a position near the forward end of the payload bay (Figure 5.2-2), where it is docked to a special berthing[1] fixture on the orbiter and remotely deployed.

The RMS handling method was selected to avoid the complexity and constraints on motion which would be required to rotate the construction fixture into position by a special mechanism. Also, subsequent flights require a similar berthing activity to attach the orbiter to the construction fixture. Remote deployment of the construction fixture was selected to facilitate rapid preparations for

[1]Berthing is defined as maneuvering two modules or spacecraft into contact using a manipulator (per Space Operations Center System Analysis Study, JSC-16244)

• **READY THE ORBITER & RMS FOR CONSTRUCTION**

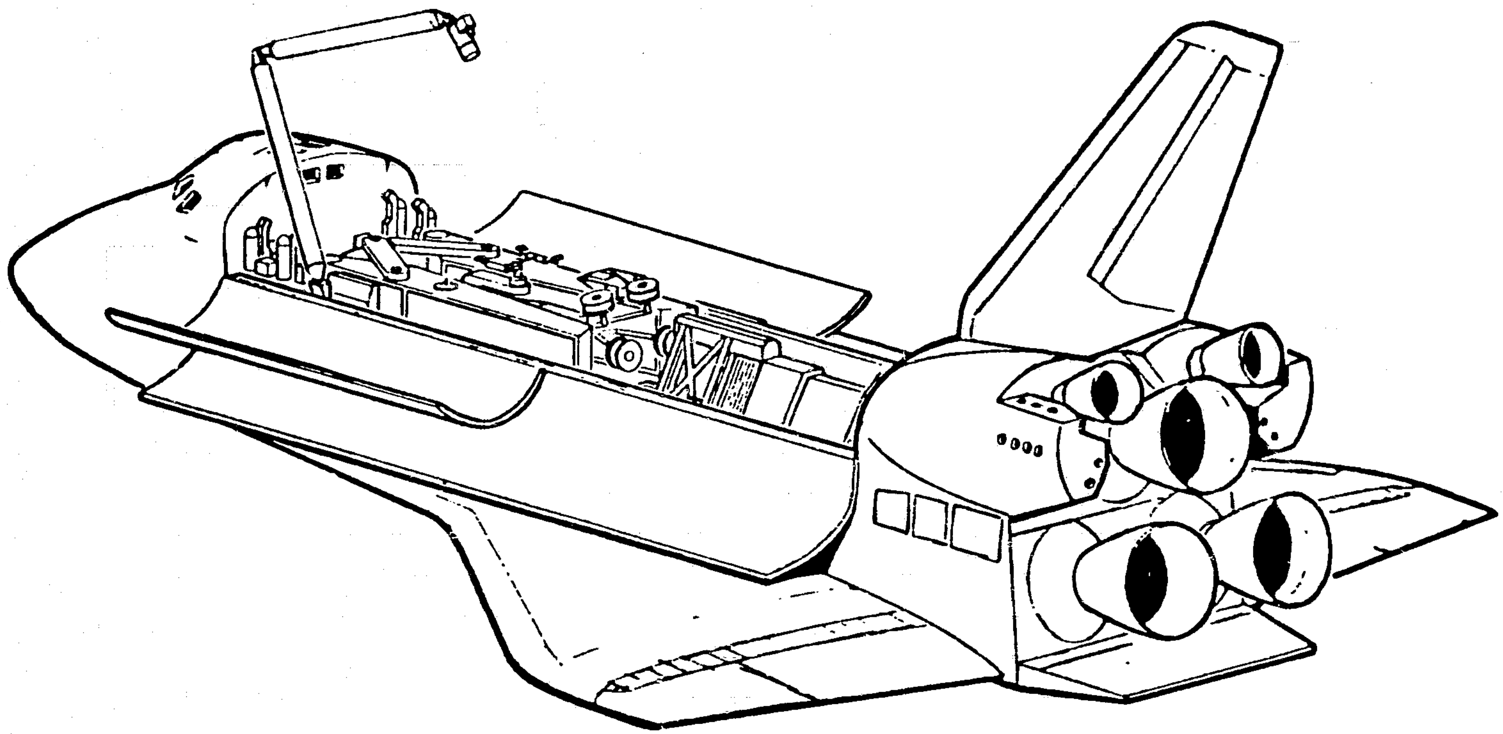

Figure 5.2-1. Initial Conditions for Construction—First Mission

• DEPLOY MAIN CONSTRUCTION FIXTURE

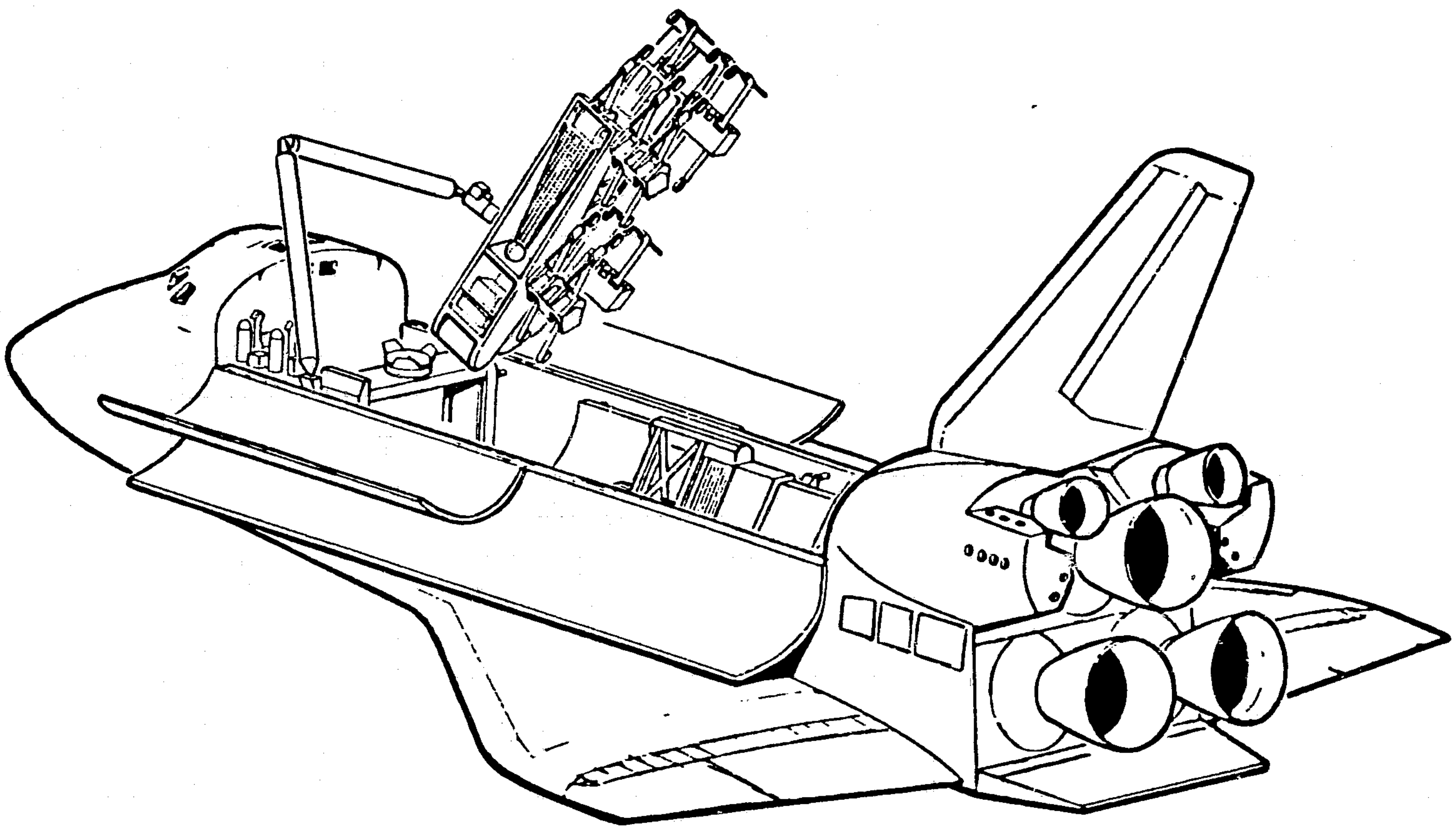

Figure 5.2-2. RMS Transporting the Construction Fixture to Operational Location

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construction, and was judged appropriate for assuming accurate alignment of the key portions of the building equipment. Also, this approach minimizes problems of electrical connections in space which are not necessarily related to the technology concerns of constructing the space fabricated platform. However, the design of the construction fixture will exercise many areas of technology related to space-deployable structures.

The next step, shown in Figure 5.2-3, is to extract the beam builder and its attached devices, transport it to the deployed construction fixture and install it on the rotary head in position for fabricating the first longitudinal beam. The attached devices include a device for installing the so-called attachment ports (for installing payloads and other components to ends of the longitudinal beam), a holder/dispenser with six attachment ports, a support tripod which interfaces with the construction fixture, lights and a TV camera.

Methods for extracting the beam builder machine (and possibly the construction fixture) are similar to initiating deployment of other large payloads by RMS. A payload installation and deployment aid (PIDA) may be required to assure safe clearances and proper orientation for RMS access to a desirable grappling point which will facilitate attachment of the beam builder to the construction fixture. This is an important issue of concern to all in-space assembly and construction operations. Ideally, the grappling point should aid the entire process of reach and vision for grappling, extraction, transport, and attachment at the assembly point and subsequent return to stowage, if required. The device for attaching the beam builder to the construction fixture is a self-aligning 3-petal device similar to the NASA PIDA interface device. However, it also includes electrical connectors for power control and sensor signals between the beam builder assembly and the construction fixture/crew cabin.

After checking out the system, fabrication begins on the first longitudinal beam as shown in Figure 5.2-4. The beam builder forms a short section, and stops. An attachment port is then installed, and fabrication continues until sufficient length is achieved. The beam is then cut, translated longitudinally a short distance by the powered rollers of the construction fixture and held while another attachment port is installed.

In parallel with the above operations, a second construction station is set up on the aft portion of the payload bay, as also shown in Figure 5.2-4. This activity could be performed later (as shown on the Logic Diagram - Figure 5.1-2), but the inactive period for the RMS during beam fabrication provides an early opportunity to accomplish a parallel operation and thus reduce overall construction time.

The beam builder complex is then rotated 120°, to a new position where it again fabricates a longitudinal beam. During this period the previously built longitudinal beam is withdrawn through the construction fixture while a harness of electrical cables is unreeled and attached to it along one face. These concepts are illustrated in Figure 5.2-5. After fabrication of the second longitudinal beam and assembly of its attachment ports, the beam builder is again rotated 120° counterclockwise and the third (apex) longitudinal beam is fabricated. During this period the first longitudinal beam (with installed electrical lines) is returned to its original fabricated position.

• INSTALL BEAM BUILDER

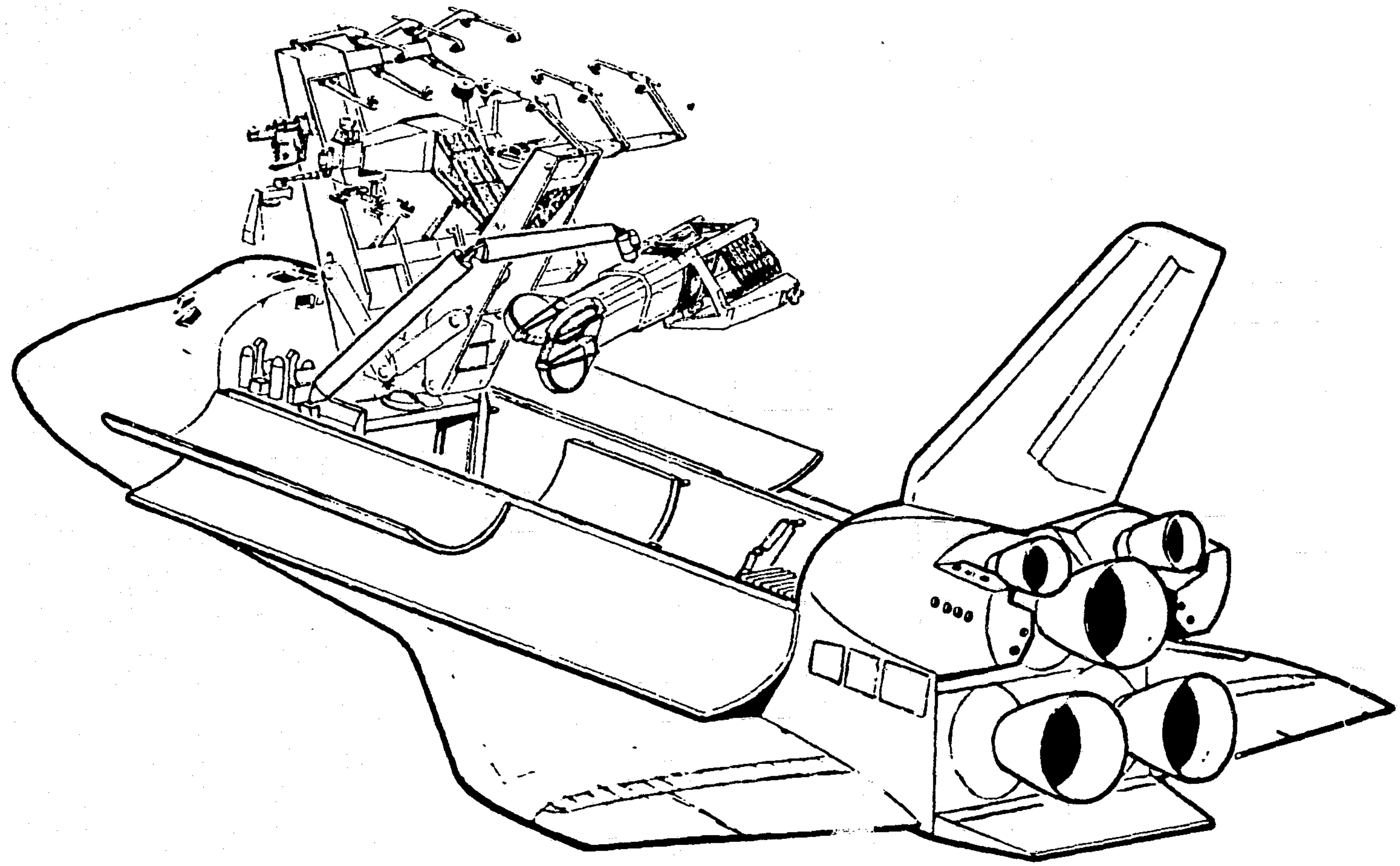

Figure 5.2-3. RMS Transporting Beam Builder to Deployed Construction Fixture

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- FABRICATE FIRST LONGITUDINAL BEAM
- SETUP WORK STATION 2

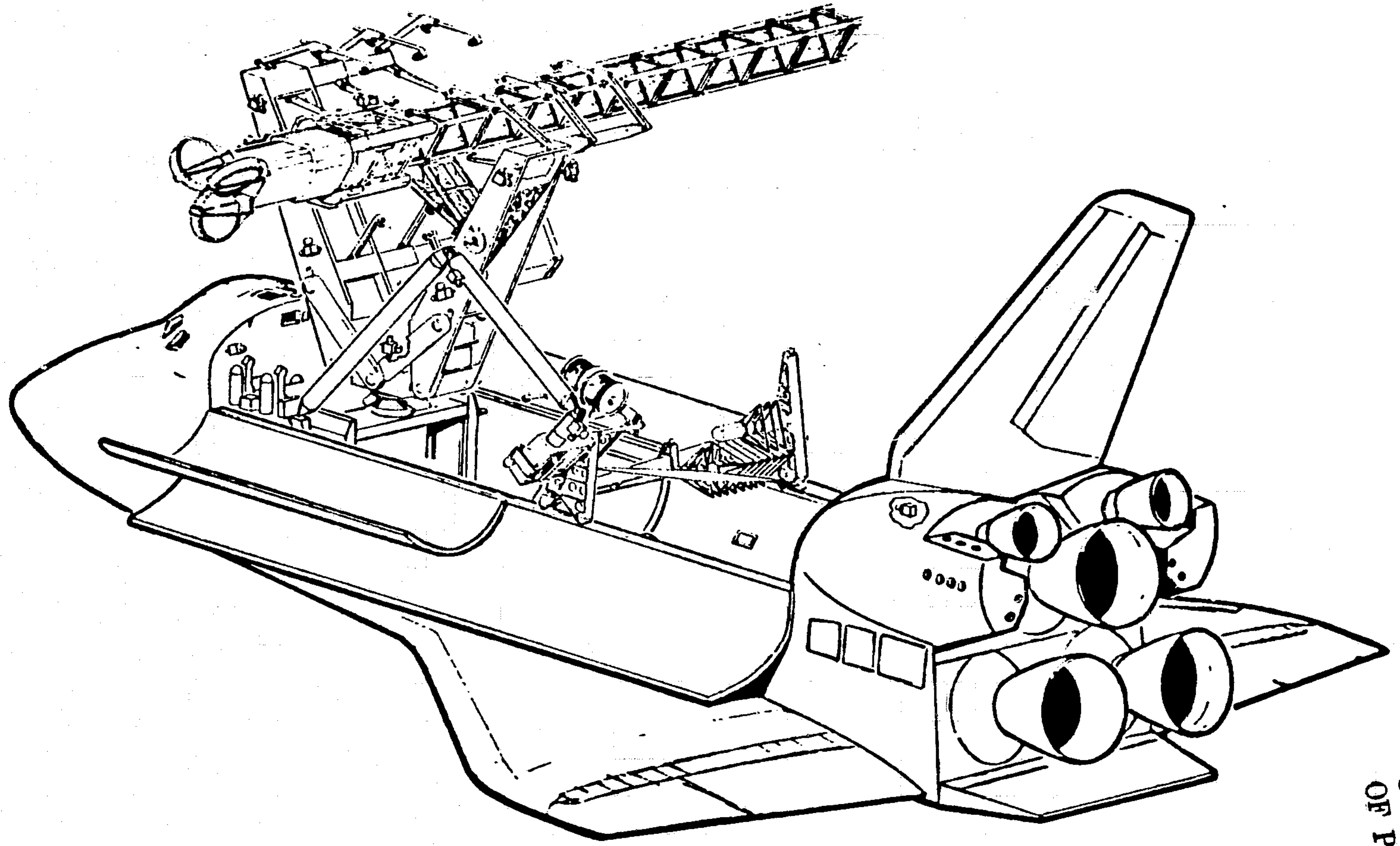


Figure 5.2-4. Fabricating the First Longitudinal Beam
and Setting Up Construction Station No. 2

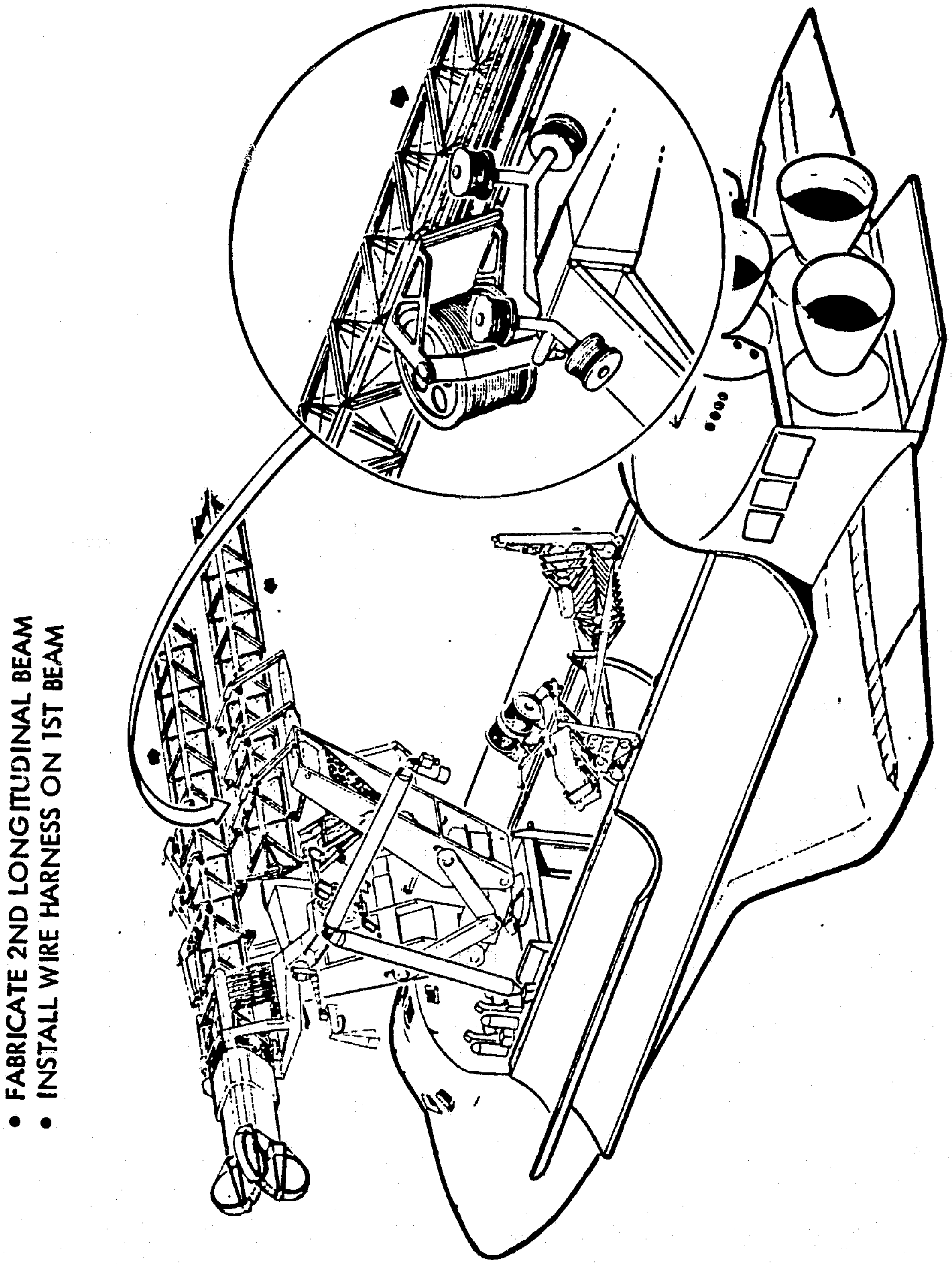


Figure 5.2-5. Fabrication of 2nd Longitudinal Beam During Wire Laying on First Longitudinal Beam

Upon completion of all three longitudinal beams, the beam builder is transported from the construction fixture to the 2nd construction station, as shown in Figure 5.2-6. The support tripod for the beam builder (which is left attached to the construction fixture during the move) is then removed from the construction fixture and stowed in the payload bay. Additional reconfigurations of the construction fixture and the attach port installation system are accomplished to prepare for fabrication and assembly of crossbeams and transverse beams. One crew member suits up and egresses through the Orbiter Air Lock at this time in order to visually inspect Construction Station No. 2 and then occupy the EVA work station on the Construction Fixture (Station No. 1). He remains in the vicinity of Construction Station No. 2 during initial fabrication of the first transverse beam, which is illustrated in Figure 5.2-7. He also observes and may help guide (by words and signals) the RMS as it grapples and connects into a special end effector which enables it to handle the beams fabricated at the second work station.

Upon completion of the first transverse beam, the RMS transports it to the forward side of the construction fixture (as shown in Figure 5.2-8) where it is transferred to a special beam positioner under control of the astronaut at the EVA work station. In the meantime, a second transverse beam is being fabricated, and the RMS must return to grasp it and transport it to the aft portion of the construction fixture. The EVA astronaut joins the first transverse beam to the longitudinal beams by electrical heating of intersection fittings (Figure 5.2-9) and makes initial hookups of the cross brace cords at the joints. He then reorients himself to deal with the 2nd transverse beam, and repeats the process.

The first (long) crossbeam fabrication is started after the 2nd transverse beam is removed from the Construction Station No. 2. This crossbeam has attachment ports at each end, docking ports for teleoperator servicing and electrical wiring as well as the intersection fittings which are on the transverse beams, as shown in Figure 5.2-10. This crossbeam is transported and joined to the longitudinals in the same manner as are the transverse beams, but also requires the EVA astronaut to connect electrical wires to the first longitudinal beam, as indicated in Figure 5.2-11. The complete structural assembly is then translated through the construction fixture to a position for assembly of a second set of three beams to form a new frame set (Figure 5.2-12). In the meantime, fabrication is initiated on the next transverse beam, which is grasped by the RMS and positioned as close as is feasible to be ready for the joining to the longitudinals. At the end of the translation an observation and record is made of the structural alignment by use of an electro-optical measuring system described later.

The complete cycle of fabrication and assembly of crossbeams and transverse beams is again repeated, with a few exceptions. The exceptions include omission of electrical lines on the short crossbeams (and thus deleting the interconnection to longitudinals) and the addition of more connections and subsequent tensioning of cross-brace cords as each beam is joined. Figure 5.2-13 illustrates the sequence of EVA crew activities during cord installation and tensioning.

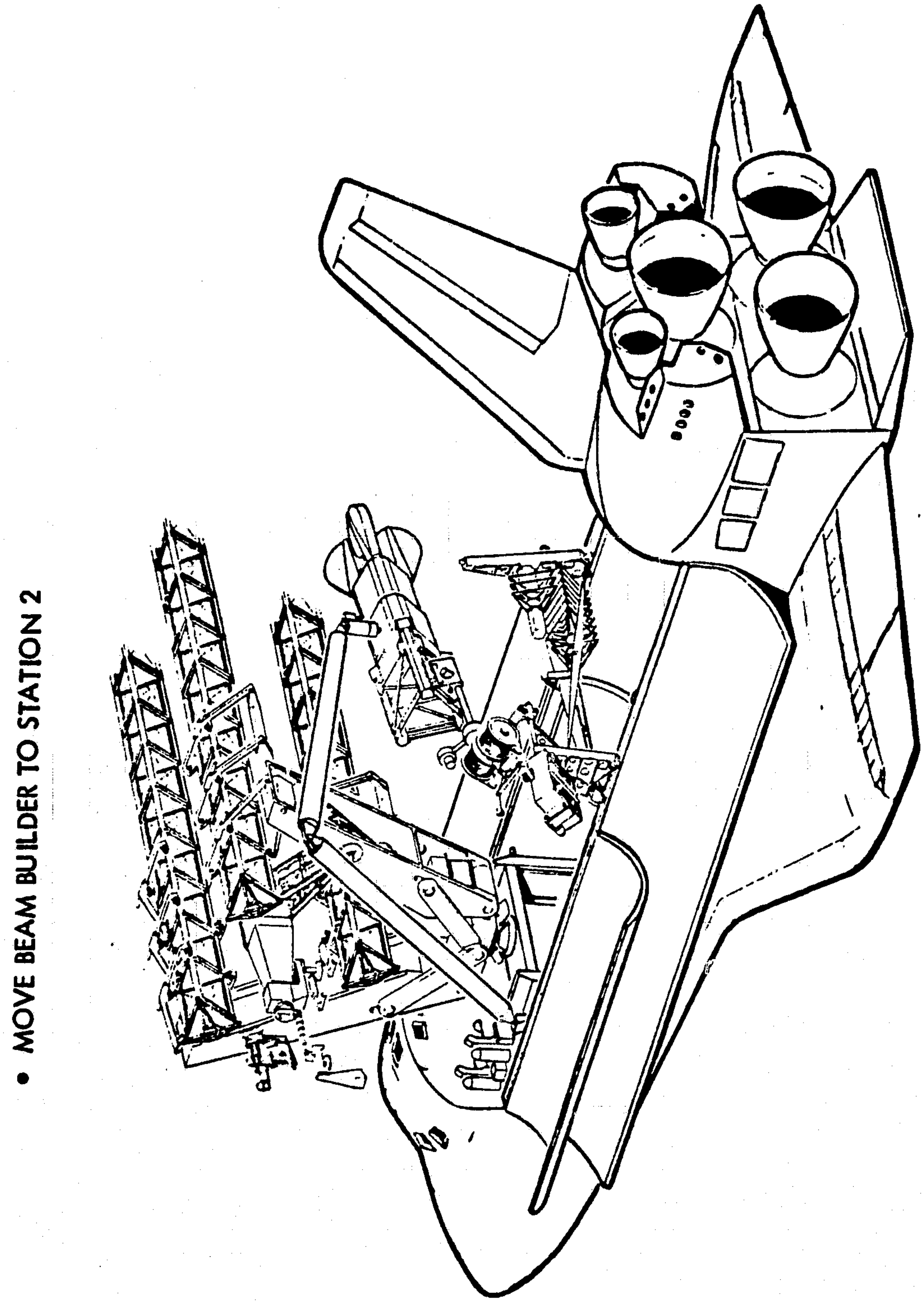


Figure 5.2-6. Moving Beam Builder to Construction Station No. 2

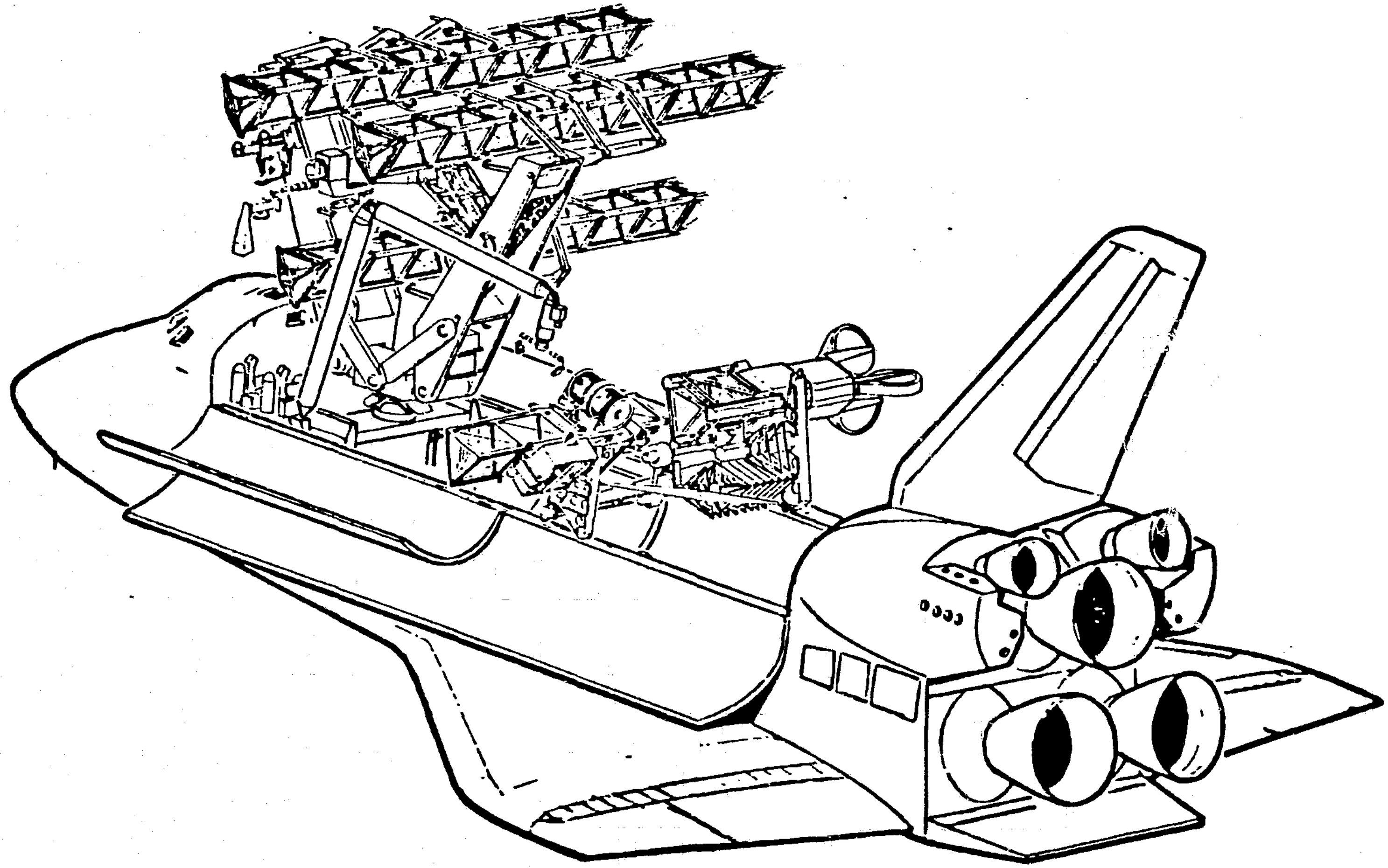


Figure 5.2-7. Fabrication of First Transverse Beam

• INSTALL TRANSVERSE BEAM NO. 1

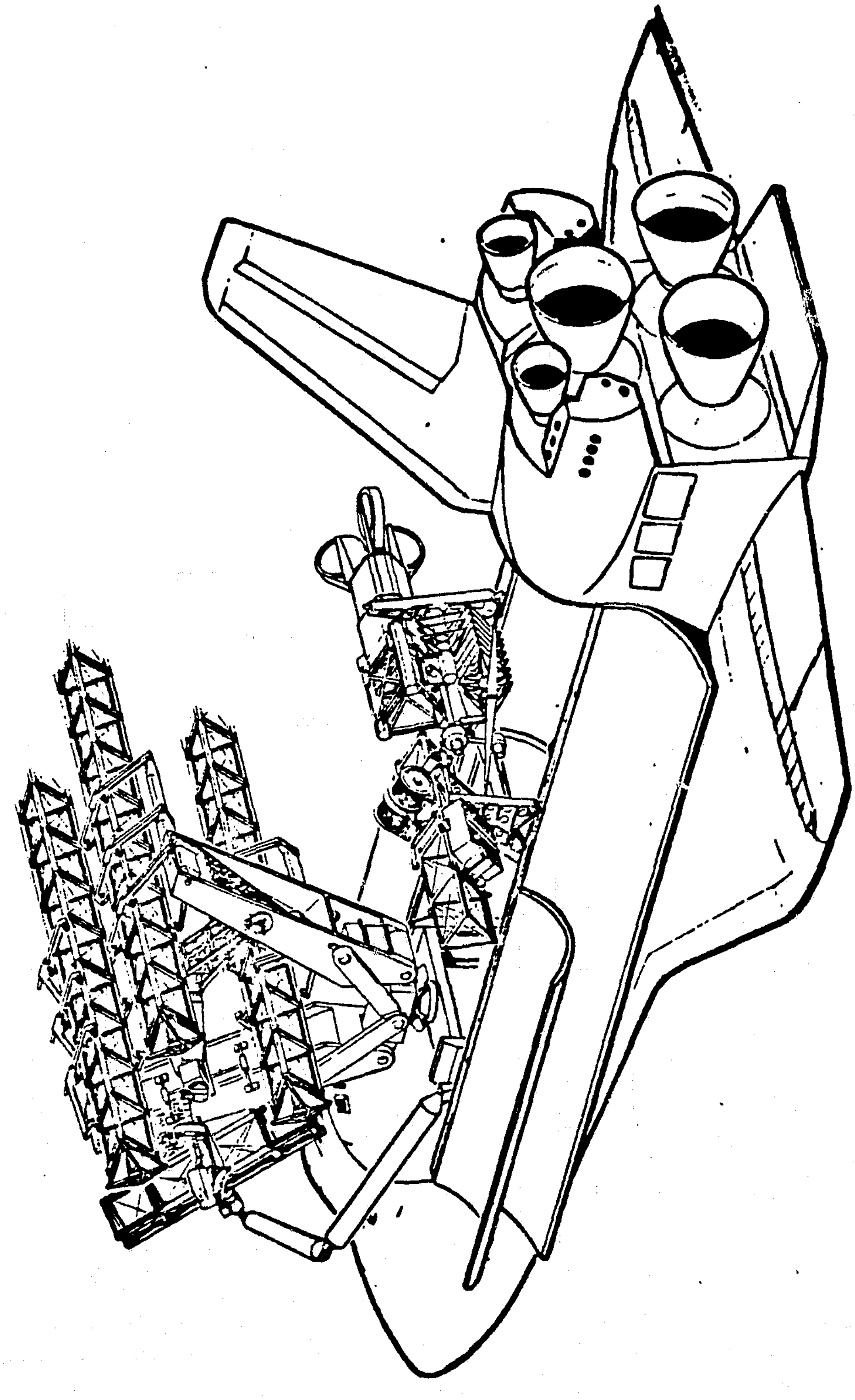
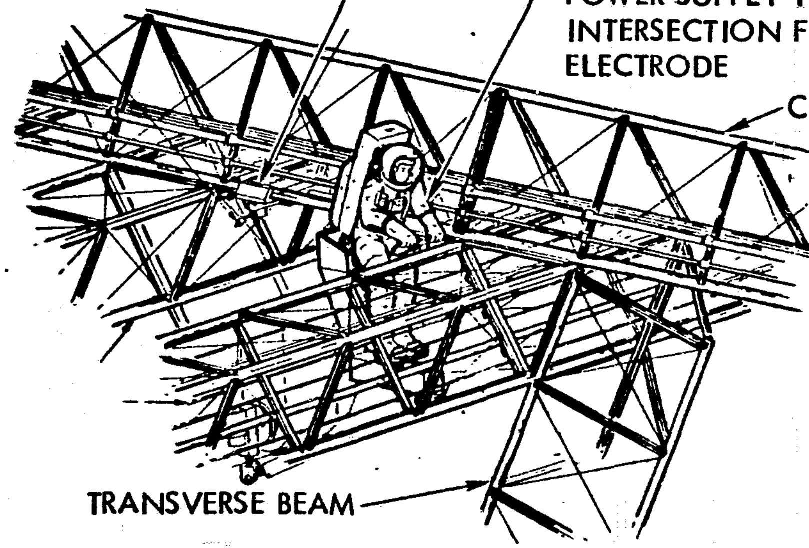


Figure 5.2-8. Transport and Installation of First Transverse Beam During Fabrication of Second



PROCEDURE

- ASTRONAUT TAKES POWER SUPPLY PIGTAIL FROM LOCATION ON BEAM POSITIONER AND MAKES CONNECTION TO ELECTRODE ON THE INTERSECTION FITTING.

- THE CHERRY PICKER IS TRANSLATED TO THE ADJACENT LONGITUDINAL BEAM WHERE THE PROCEDURE IS REPEATED.

- BOTH INTERSECTION FITTINGS REMAIN CONNECTED FOR THE REQUIRED "COOKING" PERIOD.

- WHEN THE CROSS BEAM IS WELDED TO THE LONGITUDINAL BEAM, THE POWER SUPPLY PIGTAILS ARE REMOVED

Figure 5.2-9. Procedure for Joining Crossbeams and Transverse Beams to Longitudinal Beams

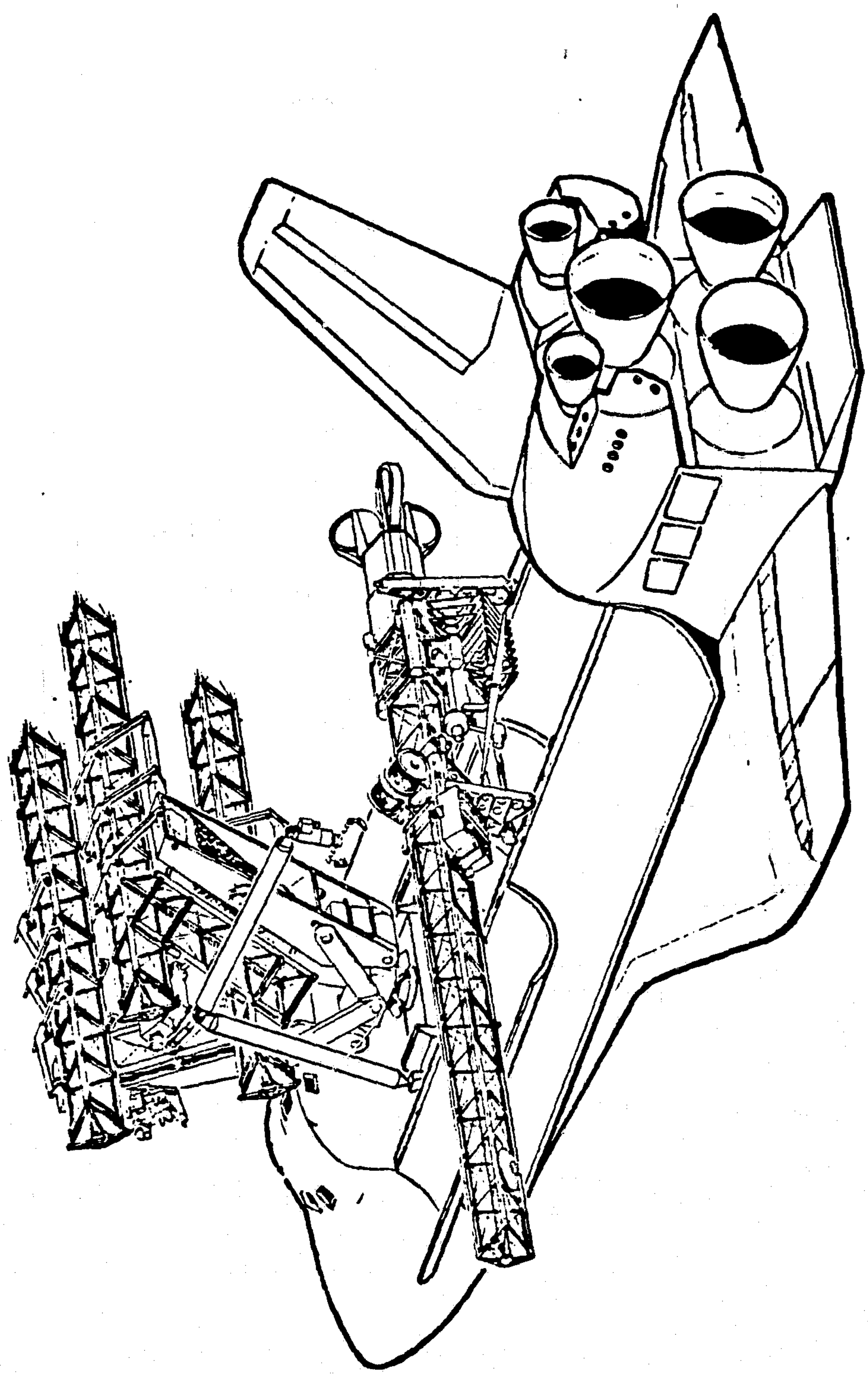


Figure 5.2-10. Fabrication of Crossbeam and Installing Bracing Cords

• PERFORM EVA ELECTRICAL HOOKUP

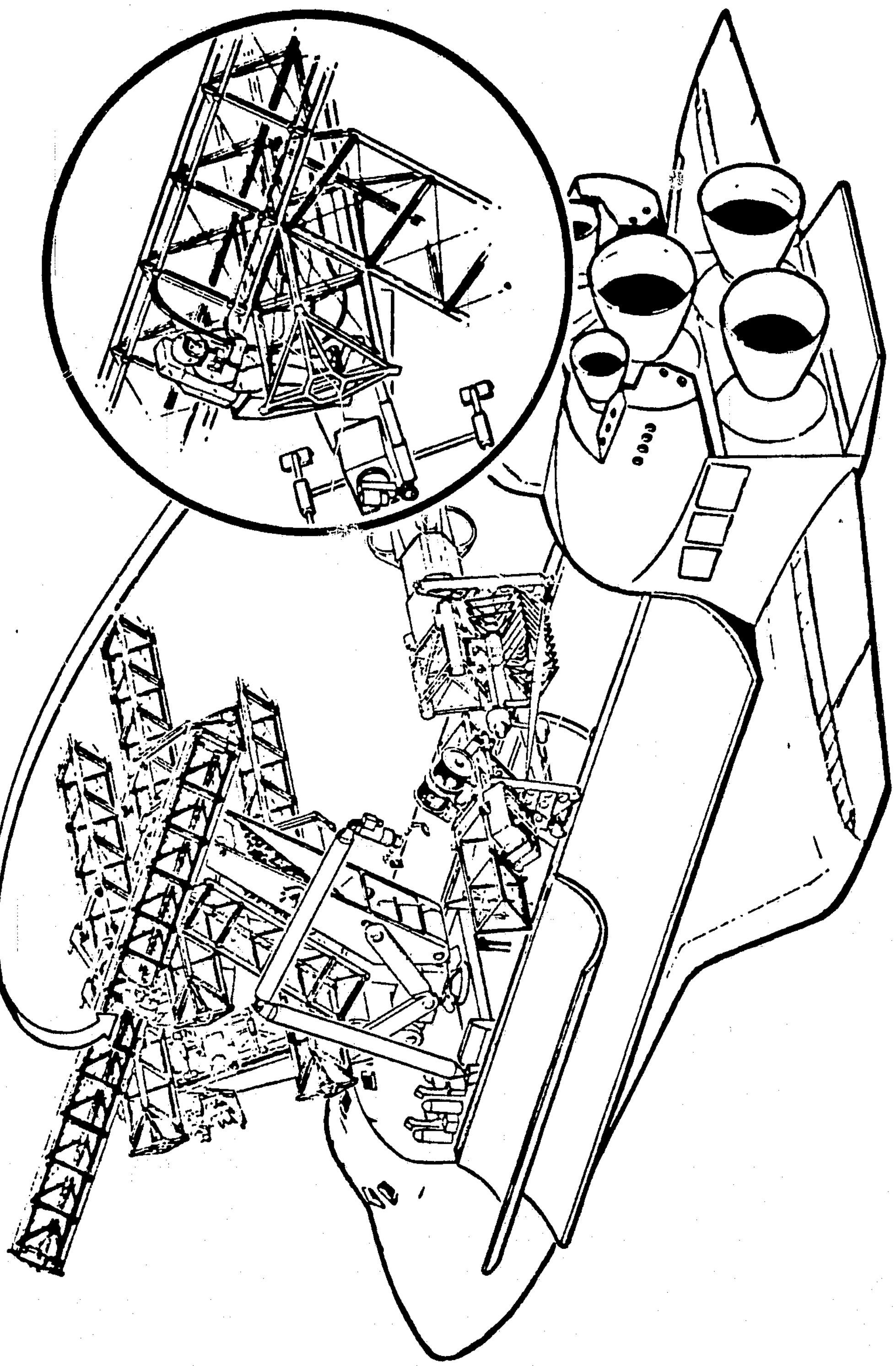


Figure 5.2-11. EVA Connection of Electrical Lines - Crossbeam to Longitudinal

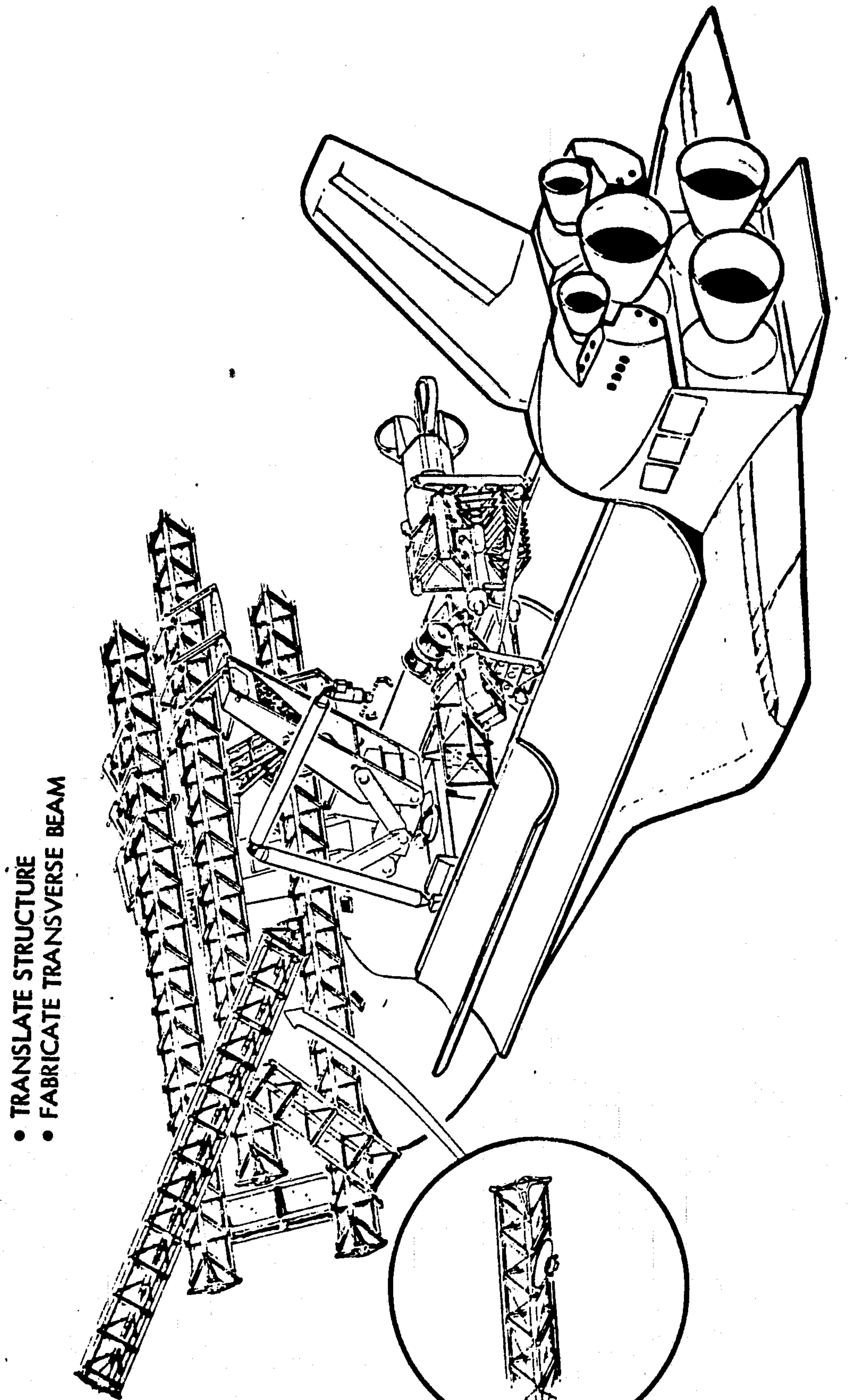


Figure 5.2-12. Translation of Platform Structural Assembly

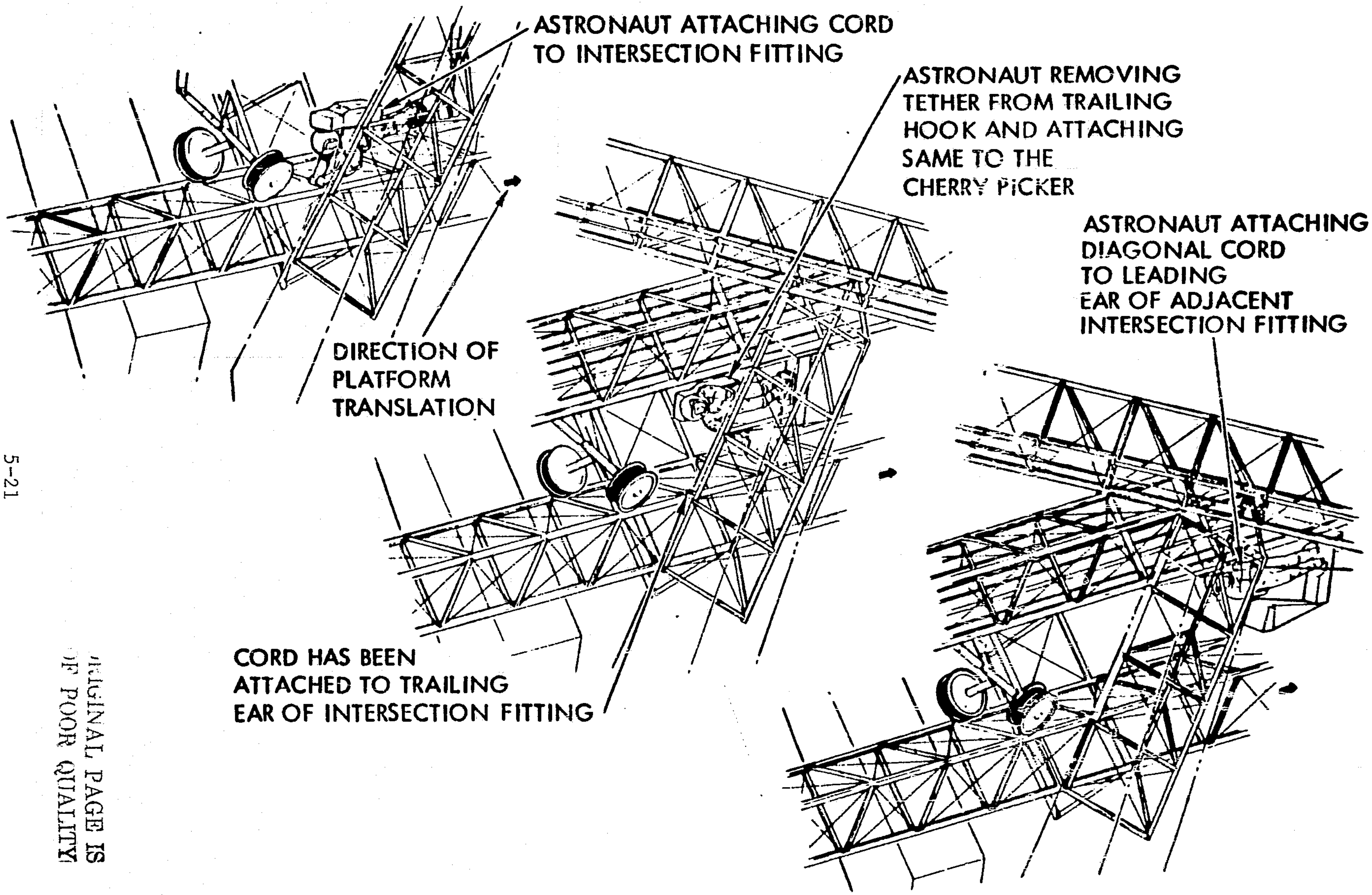


Figure 5.2-13. Bracing Cord Installation

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The process of construction continues with alternate frames containing long crossbeams and short crossbeams until completed. Then, the primary construction fixture is configured for intended operation, the second construction station is dismantled and return cargo is stowed. Figure 5.2-14 illustrates the condition prior to separation.

The return cargo includes the central portion of the primary construction fixture, the beam builder machine, attachment port holder and installation device, intersection fitting installation device and wire laying reel. During the preparation of the activity analysis it was planned to leave the modified open cherry picker (astronaut support platform) in orbit, attached to the construction fixture. However, later analysis connected with the second mission suggests a high desirability for returning this item to earth for adding a stabilizer arm, additional lights and tool support devices to make it suitable for handling struts, deployable support structures and equipment modules. It was decided to make this change in the process, but in order to conserve study resources, the Construction Activity Data Sheet was not revised.

After deployment of the libration damper RCS booms on the Construction Fixture, the system is checked out and the orbiter is separated. This completes the construction activity for the first mission.

5.3 ACTIVITY ANALYSES

The primary working analysis documents for the construction integration effort were designated as Construction Activity Data Sheets. As shown in Figure 5.3-1, these data sheets (with attachments) performed a key role in the construction system analyses. They were used for two basic purposes: (1) A record of design concept and analyses performed and (2) A requirements development document for those designs and procedures not yet clearly formulated. One Construction Activity Data Sheet was prepared for each of the designated blocks in the construction logic diagram (Figure 5.1-2). The total set of these documents is included in Appendix B.

Note that the totality of this documentation represents a majority, but not all, of key requirements for time, power/energy, crew and equipment required to accomplish the construction. It was found helpful during this period to use the metaphor of building a brick wall: The Construction Activity Data Sheets represent the "bricks", whereas certain adjustments and overall integration concerns are thought of as "mortar" which fills in the gaps between "bricks", holds them together, and forms a cohesive whole to the first mission integrated analysis description, which is presented later.

For example, each Construction Activity Data Sheet indicates which key equipment is used and for how long to accomplish the specific activity. However, it does not necessarily account for standby power demands between such activities, nor does it show duplications of lighting power where complimentary activities are performed in parallel at the same station, using the same lights. Furthermore, many functions are repeated during the course of construction, with only minor variations. A separate activity description was not created for such repetitions.

• READY CONST FIXTURE FOR UNTENDED OPS

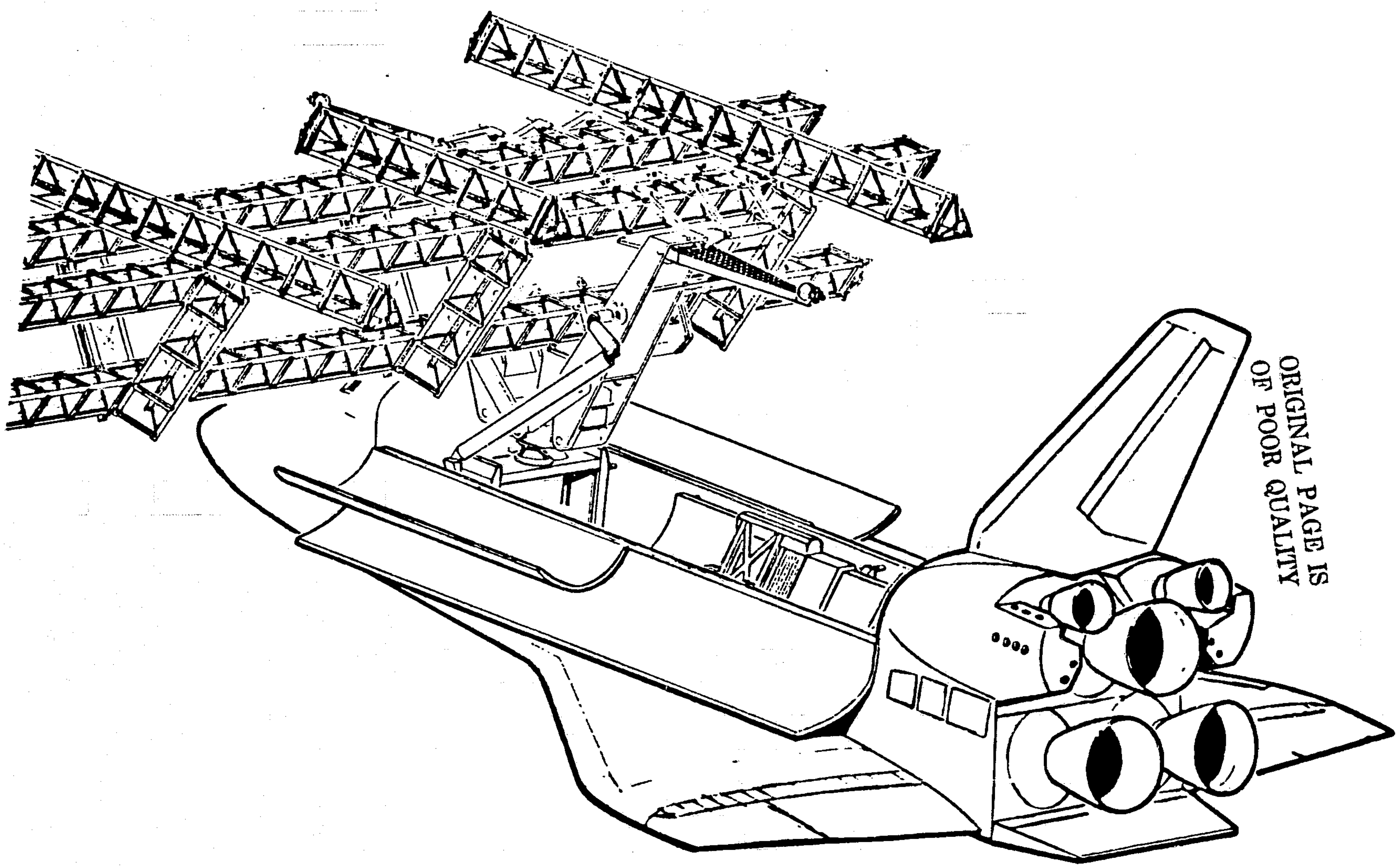


Figure 5.2-14. Preparation for Untended Operations

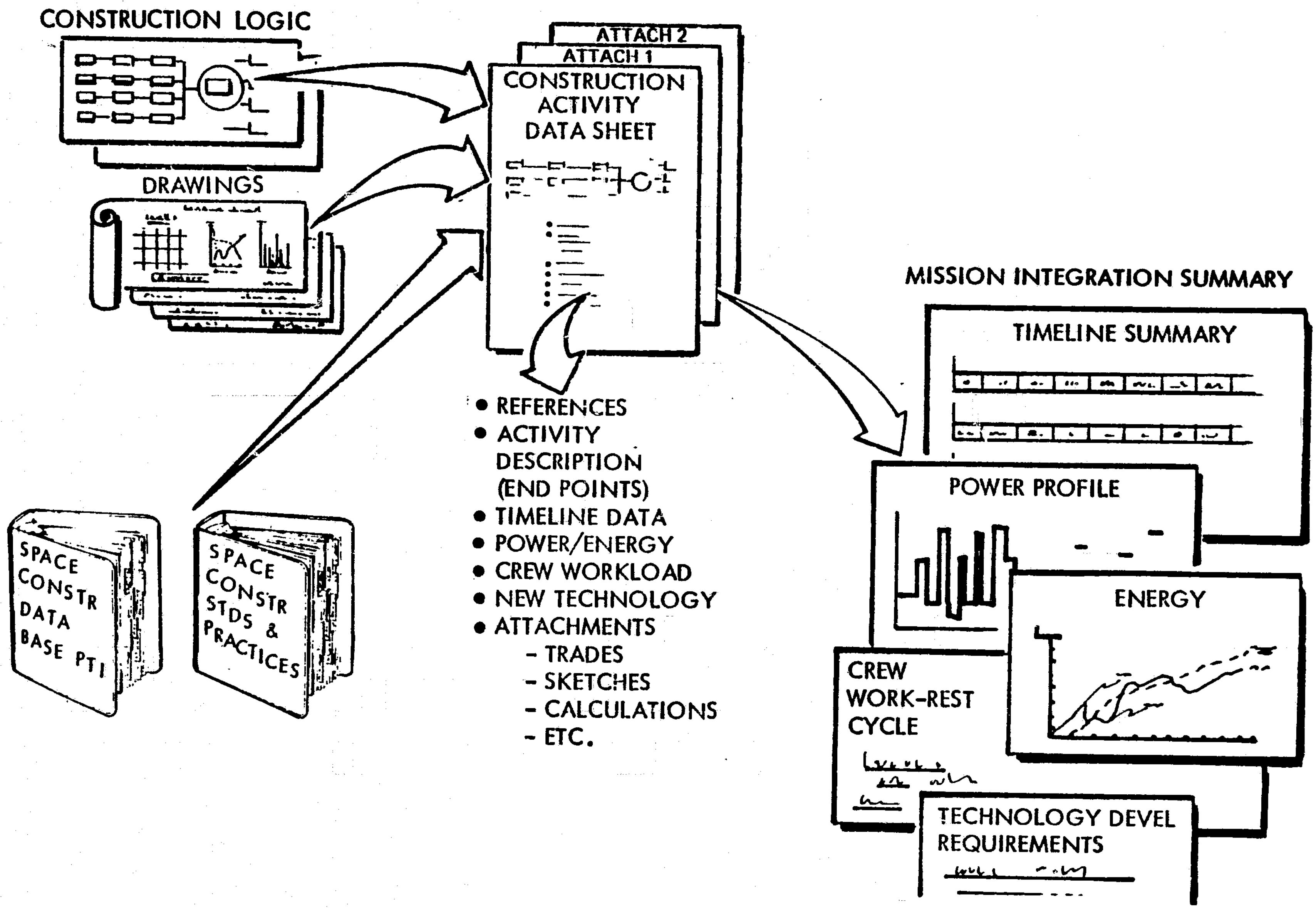


Figure 5.3-1. End-to-End Construction Activity Analysis

However, these documents provide a useful compilation of design and procedure details concerning how the construction processes was conceived and they formed a basis for later integration analyses.

One further qualification is appropriate: The Construction Activity Data Sheets were originally prepared for the platform configuration which was current at the time of preparation. As a result of the construction analysis a major change in design was made approximately mid way during the study period (near the close of the first mission analysis) in which the platform overall length was reduced from 136 meters to 108 meters. Concurrently, the long cross beams were reduced from 20 meters to 17.4 meters. It was recognized that this change implied that iterations should be accomplished on those activity data sheets which related to certain long beam fabrications and platform translation activities. However, limited resources did not permit a complete iteration for all the data sheets to reflect the new lengths. In general, the integrated timelines and integrated mission power profiles for all missions were based on the older (longer) configuration. Thus, the integrated analyses are conservative in estimating somewhat longer work period durations than needed for the final design. Where pertinent, those Construction Activity Data Sheets in Appendix B which contain time and energy estimated based on the final down-sized configuration are indicated by an asterisk.

In view of the pioneering aspects of this Space Construction System Analysis study, some comments are appropriate concerning lessons learned in analysis and documentation techniques. One such lesson is that the estimating of timelines, power and energy is facilitated by listing all three in one table of data. However, in doing so, care must be taken to note activities which contribute to power and energy demand but do not add to the time. Another observation is that the activity analysis sheets need only list key construction equipment items, tasks and formulas or rationale for estimating time, power and energy. The summarizing of total power and time for the mission is a task better suited to the integration analyses, in which all the concurrent and sequential activities are considered together on a master chart.

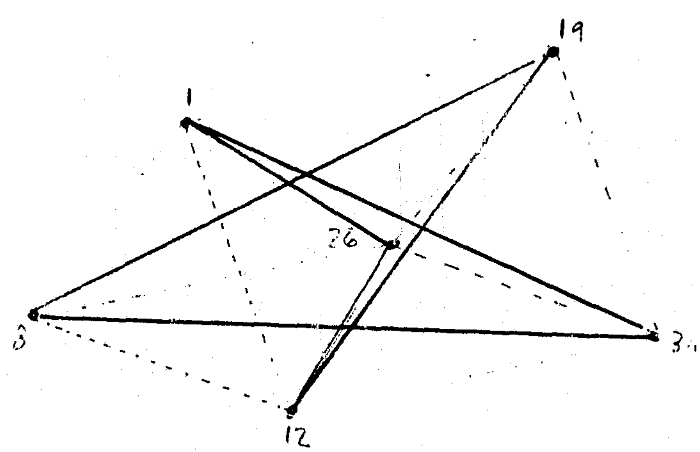
5.3.1 Structural Analysis Verification of "X"-Bracing Installation Approach

This article describes the structural analysis performed to verify the feasibility of the X-bracing installation and pretensioning construction approach described in the Construction Activity Data (11.2 - 11.3, Appendix B). The essential technique of the X-bracing operations is that in each face of the tri-beam initial pretension of the first cord is to a small load such as 66 to 112 N (15 to 25 Lbs) and that of the second cord to a load of 2360 N (530 lbs). The premise is that the first cord will then have a tension of 2360 N (530 lbs) $\pm$ 150 N (35 lbs). The structural analysis conducted validated this premise (which, incidentially, is similar to that of the astromast).

Table 5.3-1 illustrates the results of NASTRAN analyses performed on a single bay model of the tri-beam. The lowest tension force in element 12-26 is 2249 N or 111 N less than the nominal value. Further, the foregoing did not include thermal change effects. A 55^{o} C temperature change in the cord will effect a tension load change of 50 N (11.5 lbs).

Table 5.3-1. Tri-Beam Cable Pretension Loads

Cables in Place	Action	Cable Tension (N)					
		12-26	8-30	12-19	1-30	8-19	1-26
12-26	Pretension cable 12-26 to 111 N	111					
12-26, 8-30	Pretension 8-30 to 2360 N	2320	2360				
12-26, 8-30, 12-19	Pretension 12-19 to 111 N	2308	2374	111			
12-26,8-30, 12-19, 1-30	Pretension 1-30 to 2360 N	2295	2308	2310	2360		
12-26, 8-30 1-30, 12-19	Pretension 8-19 to 111 N	2311	2290	2292	2371	111	
8-19 All in place	Pretension 1-26 to 2360 N	2249	2277	2279	2309	2299	2360



It is evident from Table 5.3-1 that the tailoring of the second cord tension values can be determined during ground development tests to minimize the 111 N load reduction in cable 12-26 to approximately 40 N. Maintenance of the tension loads to +150 N in the presence of the thermal variations appears achievable even with $\pm$ 200° F relative temperature changes in the X-bracing cords.

5.4 INTEGRATION ANALYSIS

The integration analysis for the first mission was undertaken to develop a complete end-to-end synthesis of the applicable on-orbit construction process. This was the first detailed look at combining all the activities into a complete and logical sequence of work from which could be derived requirements for total time, average power, peak power, total energy, and number of crew required. Another output desired was the need for construction support equipment, including lighting and TV requirements for accomplishing the mission.

The overall process of analysis is indicated in Figure 5.4-1. Actual construction work requirements and crew activity scheduling requirements were developed in parallel and then combined into an integrated activity timeline. This output was represented graphically for visual check of parallel activities, power peaking problems, and crew utilization. Based on this integrated activity timeline, average power and exposure to peak power conditions were calculated, total energy requirements were calculated, the the results summarized in tabular format. These data were used to develop graphical presentations of the power profiles and total energy usage.

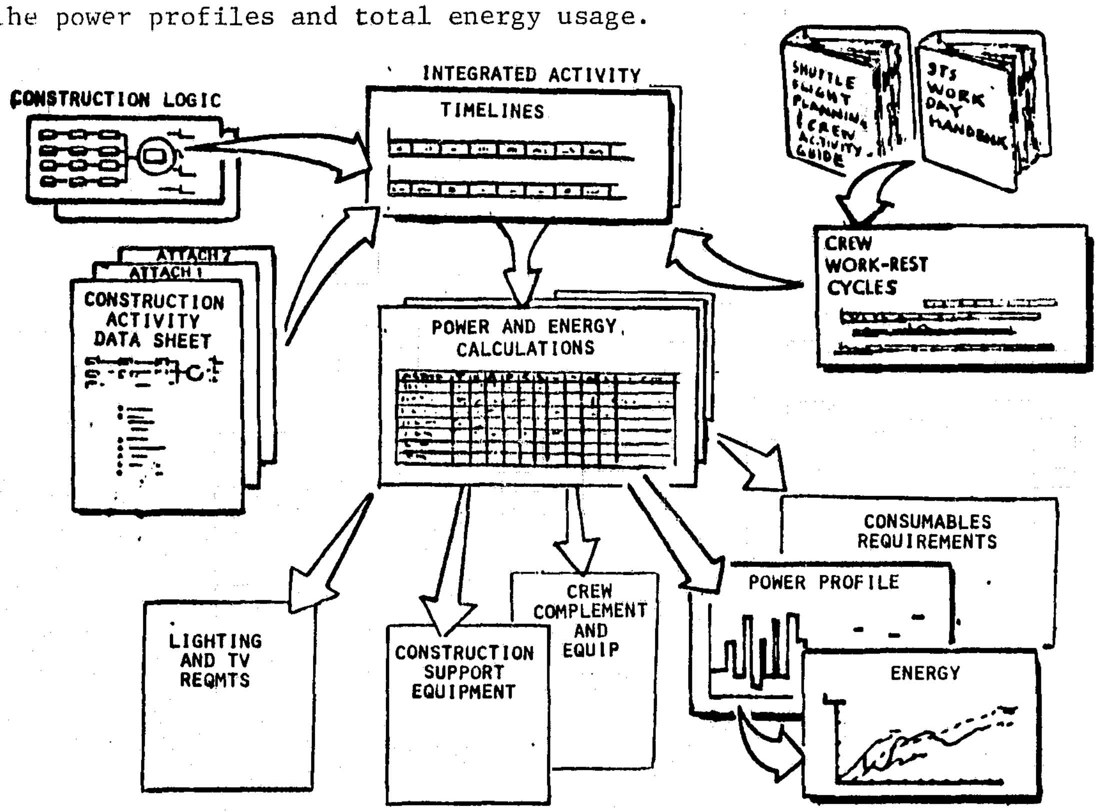


Figure 5.4-1. Integration Analysis Process

Construction support equipment needs, including lighting and TV, were developed from the *Construction Activity Data Sheets*, together with the considerations of the integrated timeline analysis, power, and energy. These outputs are summarized in following sections of this report (Sections 5.4.1 through 5.5). A similar process was used for the integration analyses of the second and third missions, which are discussed in Sections 6.0 and 7.0, respectively.

5.4.1 Integrated Activity Timelines

The detailed synthesis of the first mission construction activity began with representing the previously described major activities as bars on an integrated sequence chart, using a non-scaled, working diagram. The major purposes of this initial effort were to (1) define critical sequences of activities, (2) determined where additional, special activities might be needed for continuity and completeness, and (3) examine opportunities for parallel accomplishment of activities. Each bar was labeled with its appropriate duration in minutes (to the next largest integer minute). A preliminary review was performed to consider power, crew scheduling and equipment usage.

With the information gained from the preliminary review, a scaled timeline of the integrated activity was prepared, as shown in Figure 5.4-2. Each numbered construction activity and several non-numbered, but major "fill-in" construction activities are listed in the column on the left. For each listed activity, a bar of appropriate length is shown to the right along the time scale in the selected time frame. EVA crew rest periods and shift change periods are also shown along the bottom of the chart. The crew work shifts and rest were determined by a parallel, but separate analysis (described later) taking into account the typical work station requirements (parallel IVA and EVA work), EVA suit donning and doffing times and other standard work-rest cycle requirements derived from NASA planning documents (References 5-1, 5-2 and 5-6). See Section 5.4-2 for details of these crew activity analyses.

The integrated timeline was used as a basis for developing power profile charts, energy consumption analyses and other time-related analyses which are discussed in following sections.

The process of synthesizing the integrated activity timeline brought out the need to account for several simultaneous and interim activities and status conditions not specified during preparation of the Construction Activity Data Sheets. For example, the beam fabrication machine requires about seven minutes (430 seconds) to warm up prior to actual beam fabrication, but otherwise may be turned off completely between fabrication periods. Early in the integration analysis a general checkout activity is also presumed to be required after each relocation and setup of the beam builder machine at a new location. In lieu of detailed information on this type of activity, power requirements were assumed as equal to the average required for beam fabrication (2.24 kw). Later, the seven minutes warm up power was estimated as that required only for the heaters (1.53 kw). These warm up times were accounted for in calculating power, energy and time, but do not show as blocks of activity on Figure 5.4-2.

Similarly, the Remote Manipulator System (RMS) was assumed to require standby heating (at 1.050 kw) on a 50% duty cycle basis most of the time during construction activity. In addition, it was assumed the RMS arm would be "parked" at such times in advantageous position for use of the wrist light and wrist TV c[illegible] (together with its heater, also operating on a 50% duty cycle). The a[illegible] thus function as an auxiliary "camera stand" to provide alternate viewing ang[illegible]s of construction operations. Such standby status conditions are not specified in Figure 5.4-2, primarily to avoid further visual clutter.

However, the analyst needs such information on a working document as a reminder of power demands.

Another consideration of major power demand significance is that of general lighting, such as by use of orbiter payload bay lights, construction fixture lights and other specific lamps. A working document should list each lamp and show a bar of "activity" when it is turned on. TV cameras, tilt and pan mechanisms, control/display items, etc. also are of some concern, but may not draw significant power in comparison to uncertainties of the RMS or of beam fabrication.

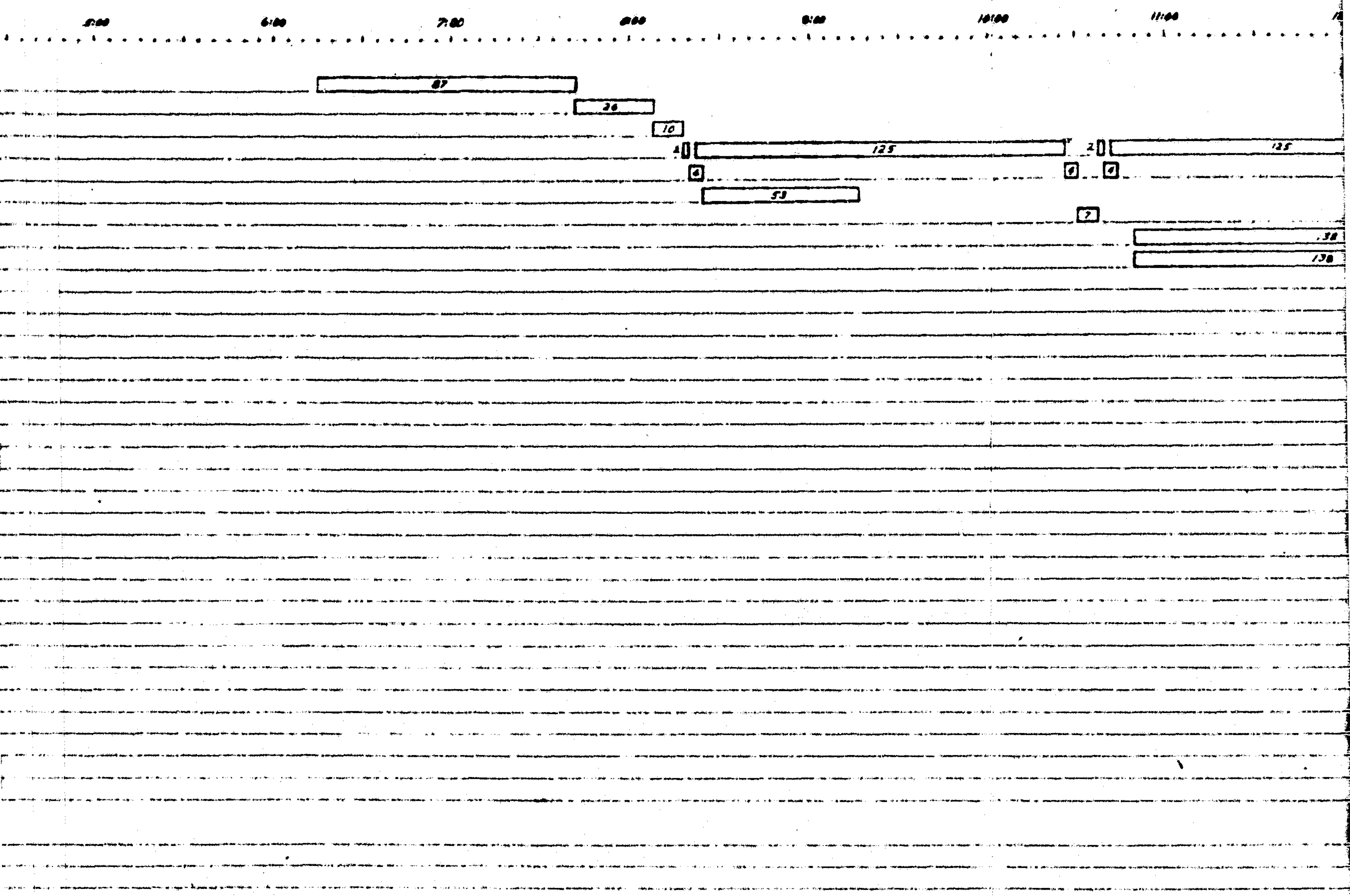
The detailed analytical effort involved in calculating power profiles and energy from a chart such as shown in Figure 5.4-2 is quite time consuming and tedious. A portion of the activity is essentially repetitious but is slightly different for each cycle, primarily because of crew rest and crew exchange period delays. For purposes of this preliminary type of analysis it was felt appropriate to create a somewhat artificial timeline segment chart for a representative cycle. The resulting chart is shown in Figure 5.4-3. In preparing this chart the activities were first sequenced as if a non-tiring robot was accomplishing the work. Then the probable requisite crew rest periods were added to compile a representative total time. Peak and average power estimates based on such a chart are slightly higher than expected in practice, but total energy should be very closely approximated. The chart cycle includes one set of activities for fabricating a frame with a short crossbeam and one for a frame with a long crossbeam, with associated wiring installations and connections. Approximately 5 such cycles are required after assembly of the first frame which has a long crossbeam, and this was the basis for the energy estimation. In fact, the last cycle is again slightly different, because of tying off the cross-brace cords, the small extension stubs of the longitudinals and the lack of need for a final translation and subsequent structural alignment check.

In the case of synthesizing timelines for a phase C-D study, it would be advantageous to set up each cycle with crew rest periods at common times in each sequence, so that each cycle is exactly repetitious to the degree possible. This would ease the difficulty reduce cost, mission planning and crew training. However, the potential need for flexibility in on-site activity scheduling should be considered and provisions made for computer-generated automatic checklists which would account for necessary logic of construction processes and help minimize effects of unforeseen delays by "work around" methods.

MISSION TIME G.E.T. 0:00 1:00 2:00 3:00 4:00

1.0 ERECT & DEPLOY CONSTRUCTION FIXTURE
2.0 INSTALL BEAM BUILDER ON CONSTRUCTION FIXTURE
CHECKOUT BEAM BUILDER
3.1 FABRICATE LONGITUDINAL BEAM
3.2 INSTALL ATTACH PORTS ON LONGITUDINAL BEAM
7.0 SETUP CONSTRUCTION STATION No. 2
4.0 REPOSITION BEAM BUILDER 120°
5.1 WITHDRAW LONGITUDINAL BEAM No. 1
5.2 INSTALL ELECTRIC LINES ON LONGITUDINAL BEAM No. 1
6.0 RETURN LONGITUDINAL BEAM No. 1 TO FABRICATION POSITION
8.1 RELOCATE BEAM BUILDER TO CONSTRUCTION STATION No. 2
CHECKOUT BEAM BUILDER AT CONSTRUCTION STATION No. 2
RMS END EFFECTOR CHANGE
EVA ASTRONAUT EGRESS & INSPECTION TOUR
9.1 FABRICATE TRANSVERSE BEAM
9.2 JOIN INTERSECTION FITTINGS TO TRANSVERSE BEAM
10.0 TRANSPORT TRANSVERSE BEAM
8.2 RECONFIGURE CONSTRUCTION FIXTURE & OCCUPY EVA STATION
11.1 JOIN TRANSVERSE BEAM TO LONGITUDINAL BEAMS
11.2A INITIAL CONNECTION OF X-BRACE CORDS
11.2B JOIN X-BRACE CORDS TO LEADING & TRAILING EARS
11.3 TENSION X-BRACE CORDS
12.1 TRANSPORT TRANSVERSE BEAM
12.2 FABRICATE CROSS BEAM (LONG/SHORT)
12.3 INSTALL ATTACH PORTS ON CROSS BEAM
12.4 INSTALL ELECTRIC LINES ON CROSS BEAM
12.5 INSTALL TELEOPERATOR DOCKING PORTS
13.0 TRANSPORT CROSS BEAM
14.0 CONNECT ELECTRIC LINES FROM CROSS BEAM TO LONGITUDINAL BEAM
15.0 TRANSLATE STRUCTURE ONE BAY LENGTH
16.0 CHECK STRUCTURAL ALIGNMENT
17.1 CONFIGURE CONSTRUCTION FIXTURE FOR UNTENDED OPERATIONS
17.2 STOW RETURN CARGO IN PAYLOAD BAY

EVA ASTRONAUT No. 1 TRANSPORT / REST / LUNCH
EVA ASTRONAUT No. 2 TRANSPORT / REST / LUNCH
EVA ASTRONAUT No. 3 TRANSPORT / REST / LUNCH



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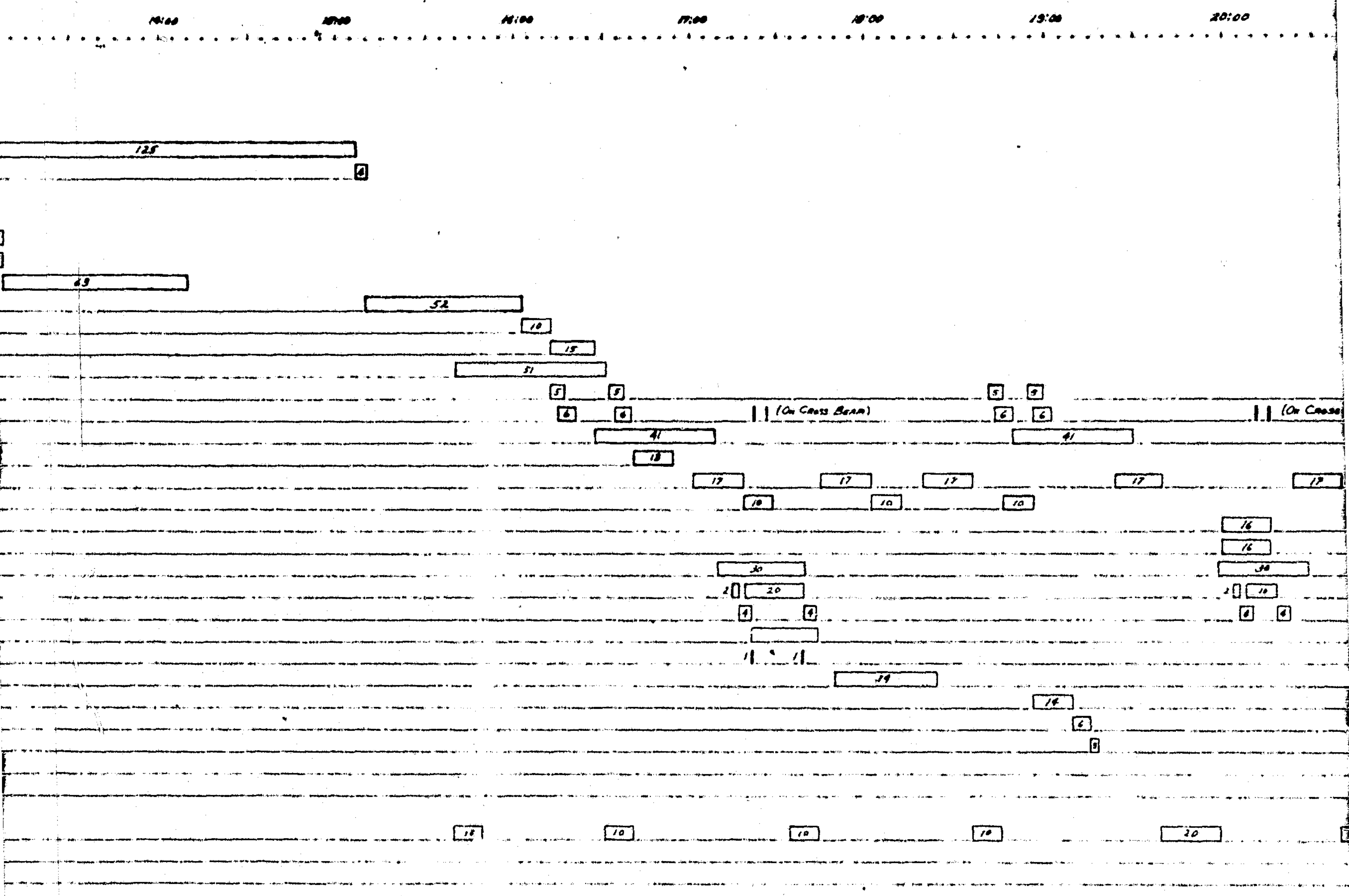

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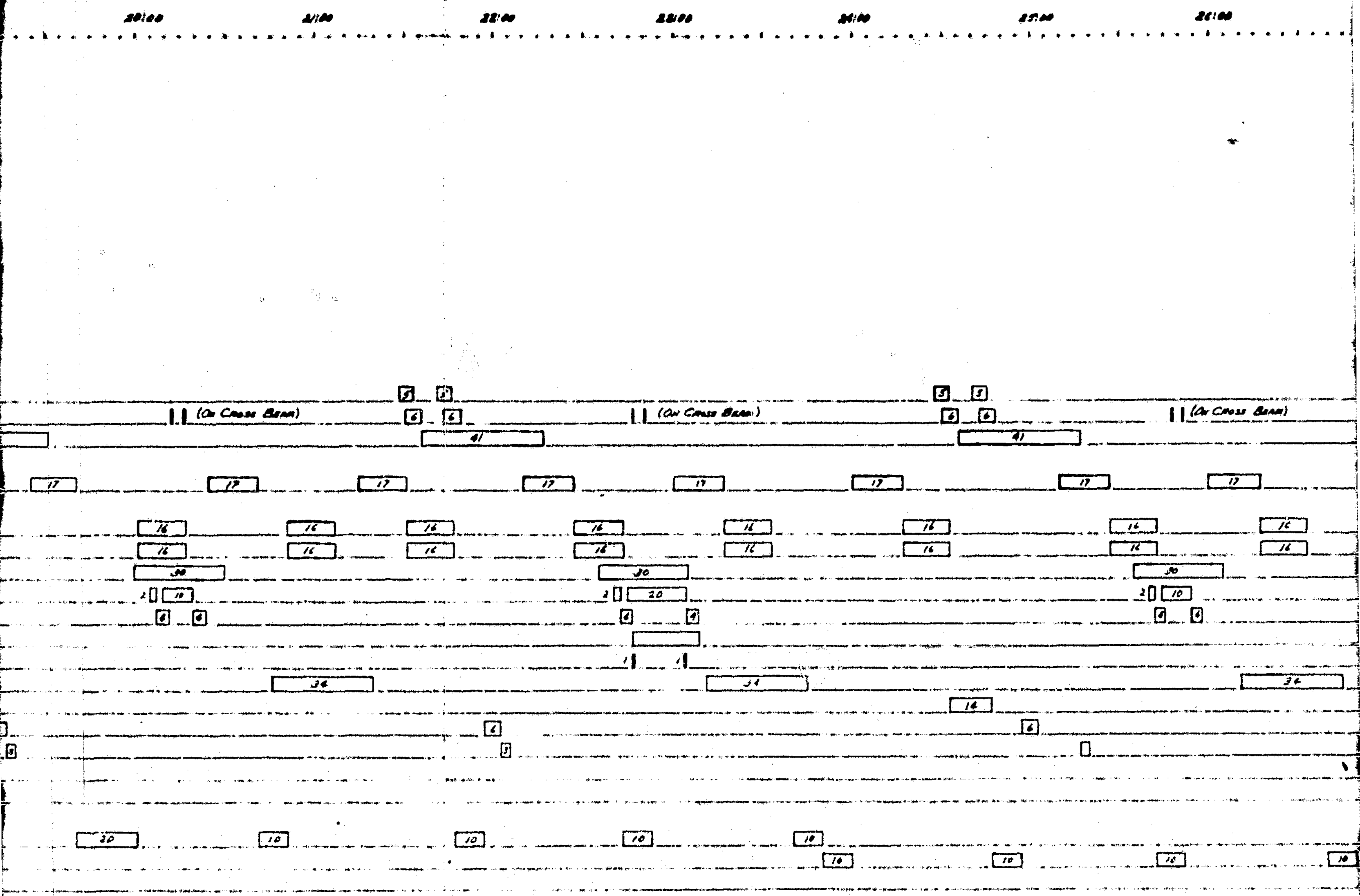
20:00
21:00
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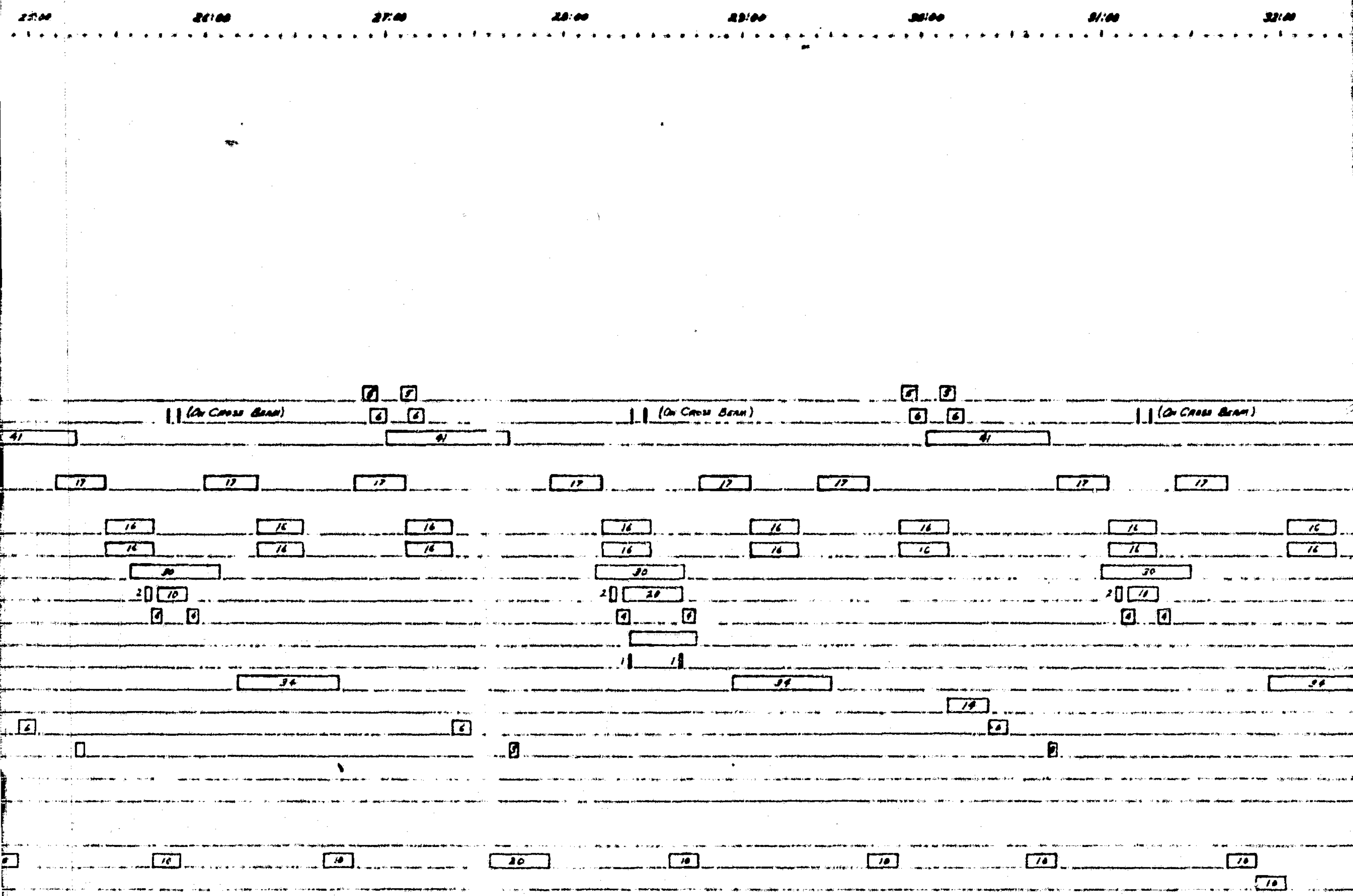

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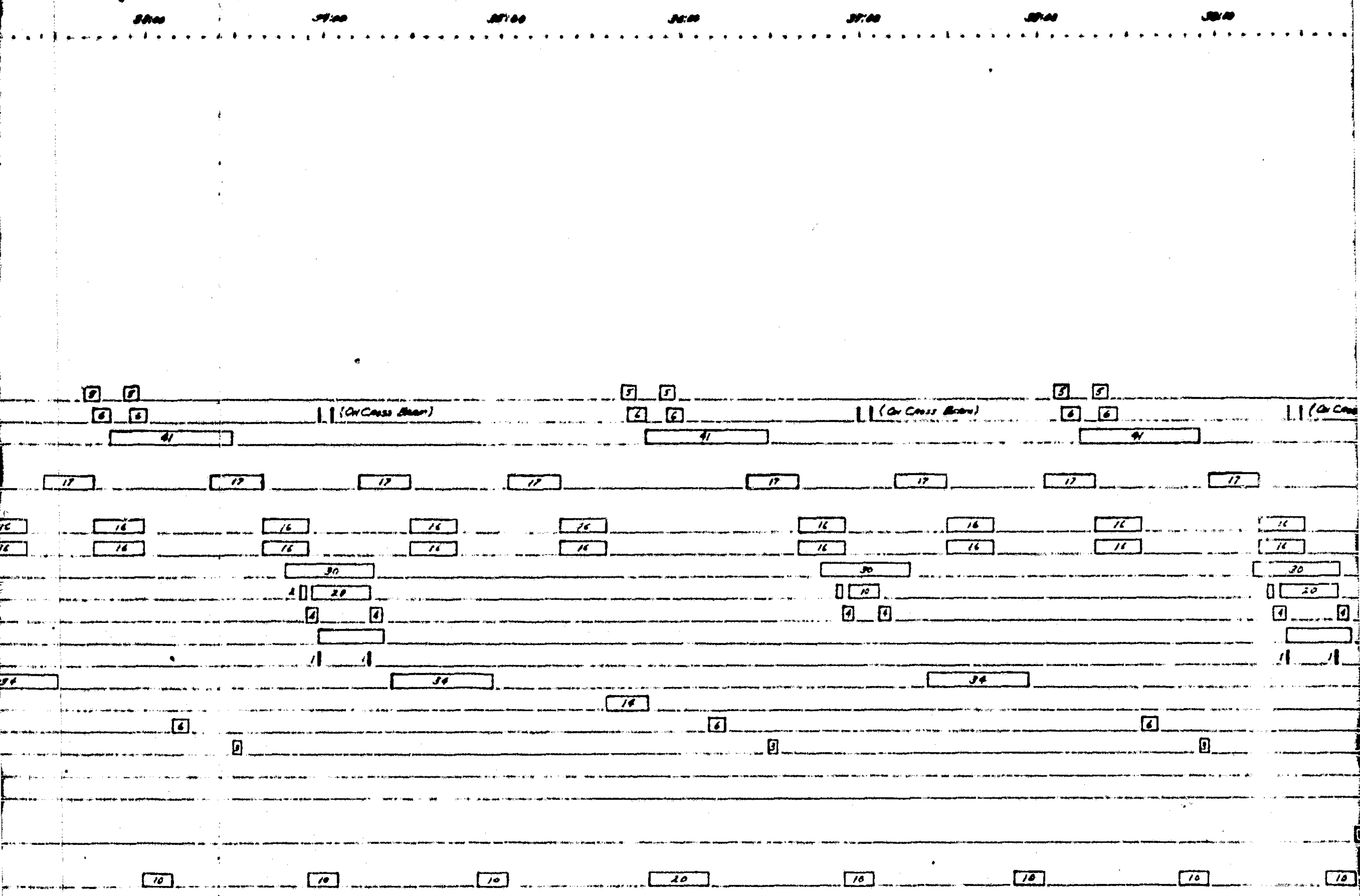

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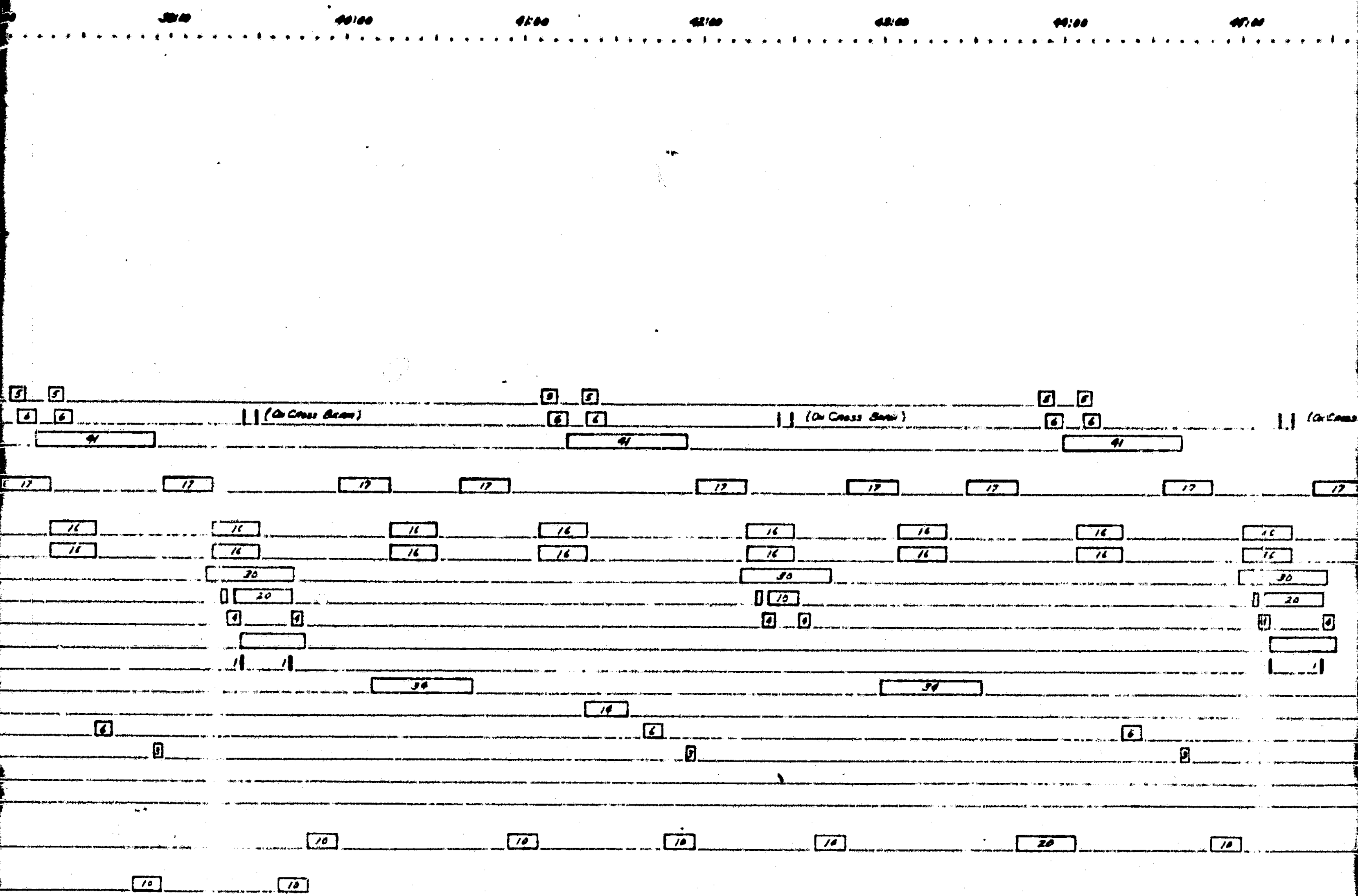

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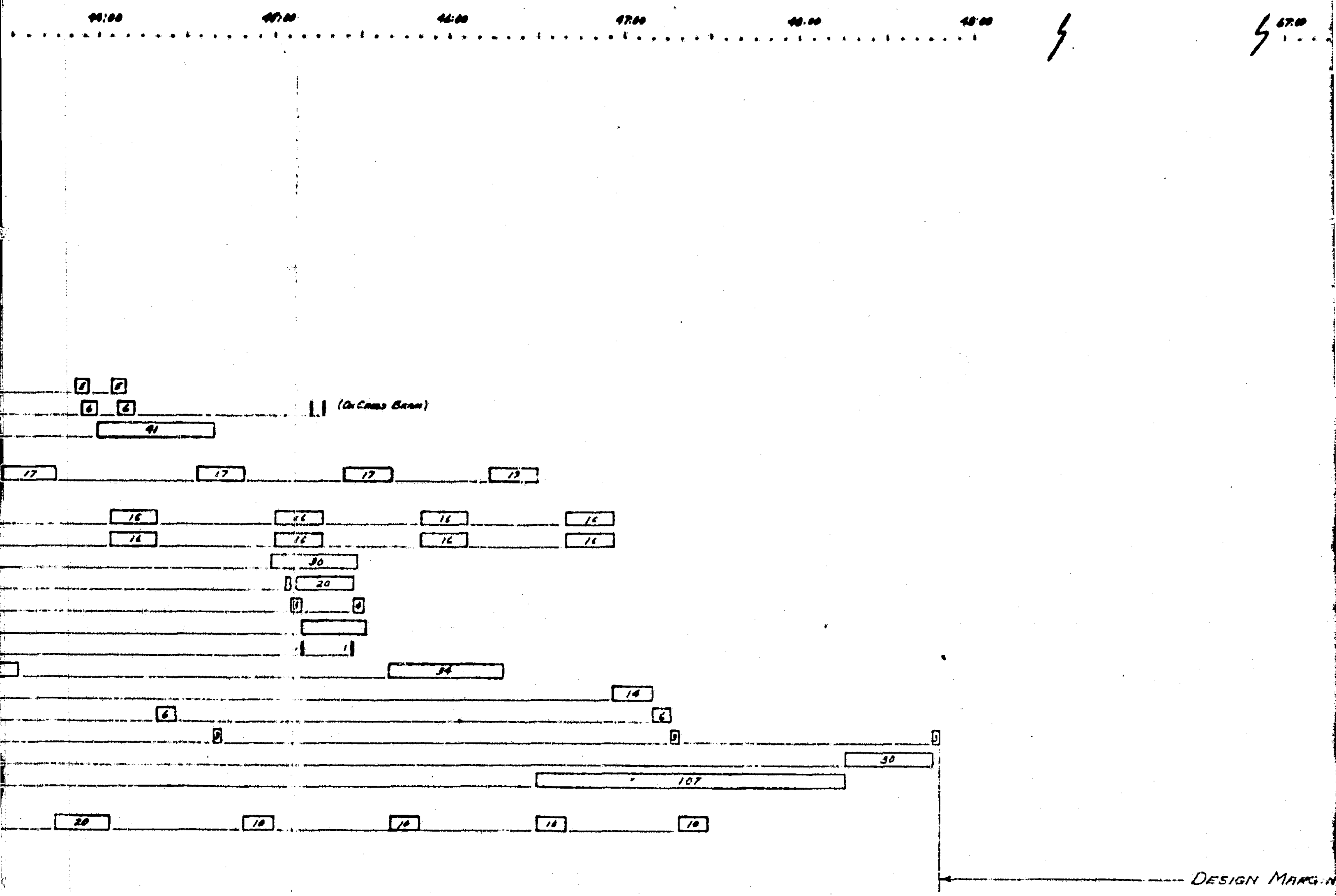

Figure 5.4-2. Integration Activity Timelin

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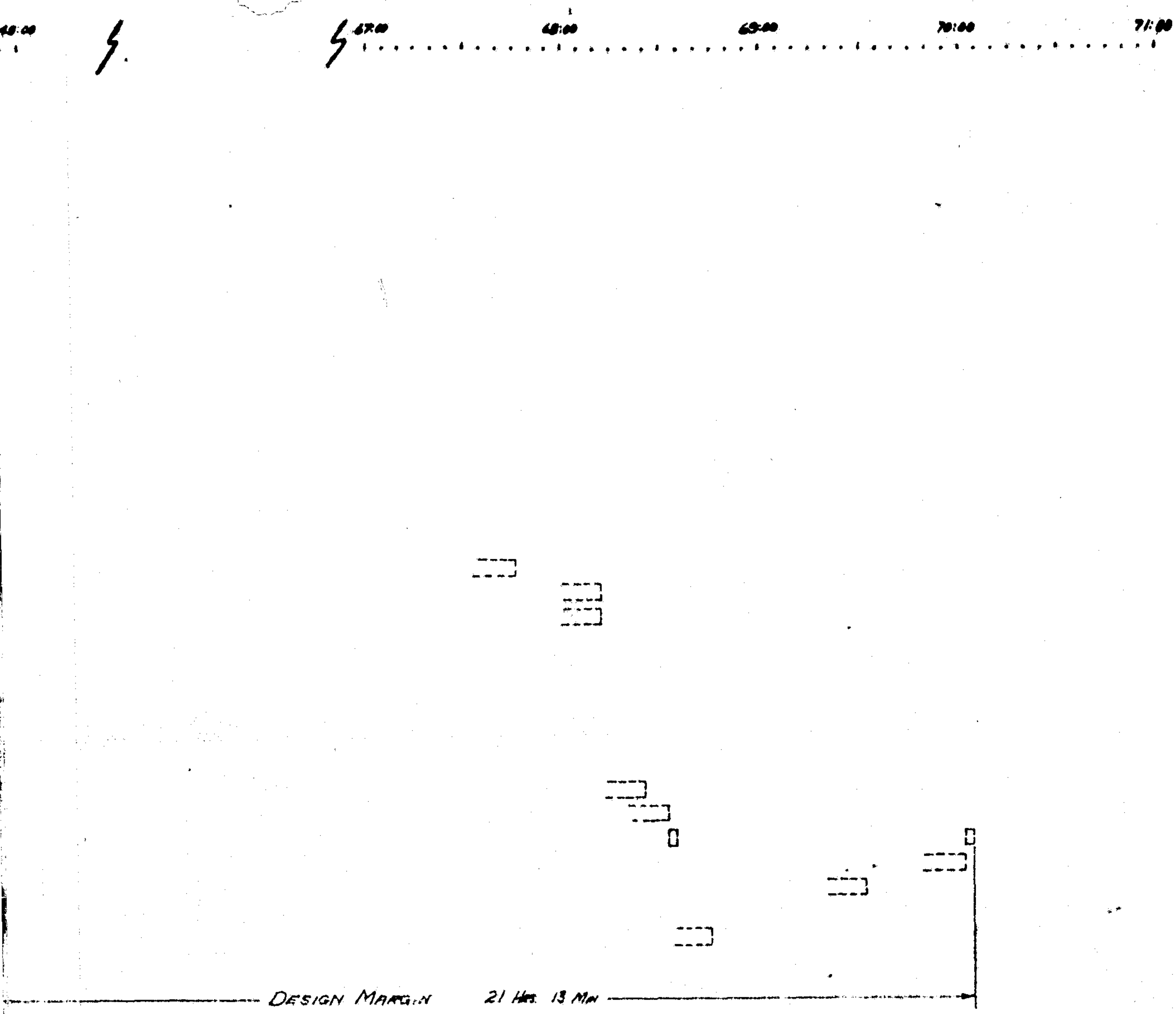

Rockwell International	
INTEGRATED ACTIVITY TIMELINE 1ST MISSION	42662-75

Integration Activity Timeline - First Mission

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MISSION TIME - G.E.T.

ACTIVITY

9.1 FABRICATE TRANSVERSE BEAM ____

9.2 JOIN INTERSECTION FITTINGS TO TRANSVERSE BEAM ____

10.0 TRANSPORT TRANSVERSE BEAM ____

11.1 JOIN TRANSVERSE BEAM TO LONGITUDINAL BEAMS ____

12.2B JOIN X-BRACE CORDS TO LEADING & TRAILING EARS ____

11.3 TENSION X-BRACE CORDS ____

12.1 TRANSPORT TRANSVERSE BEAM ____

12.2 FRABRICATE CROSS BEAM (SHORT/LONG) ____

12.3 INSTALL ATTACH PORTS ON CROSS BEAM ____

12.4 INSTALL ELECTRIC LINES ON CROSS BEAM ____

12.5 INSTALL TELEOPERATOR DOCKING PORTS ____

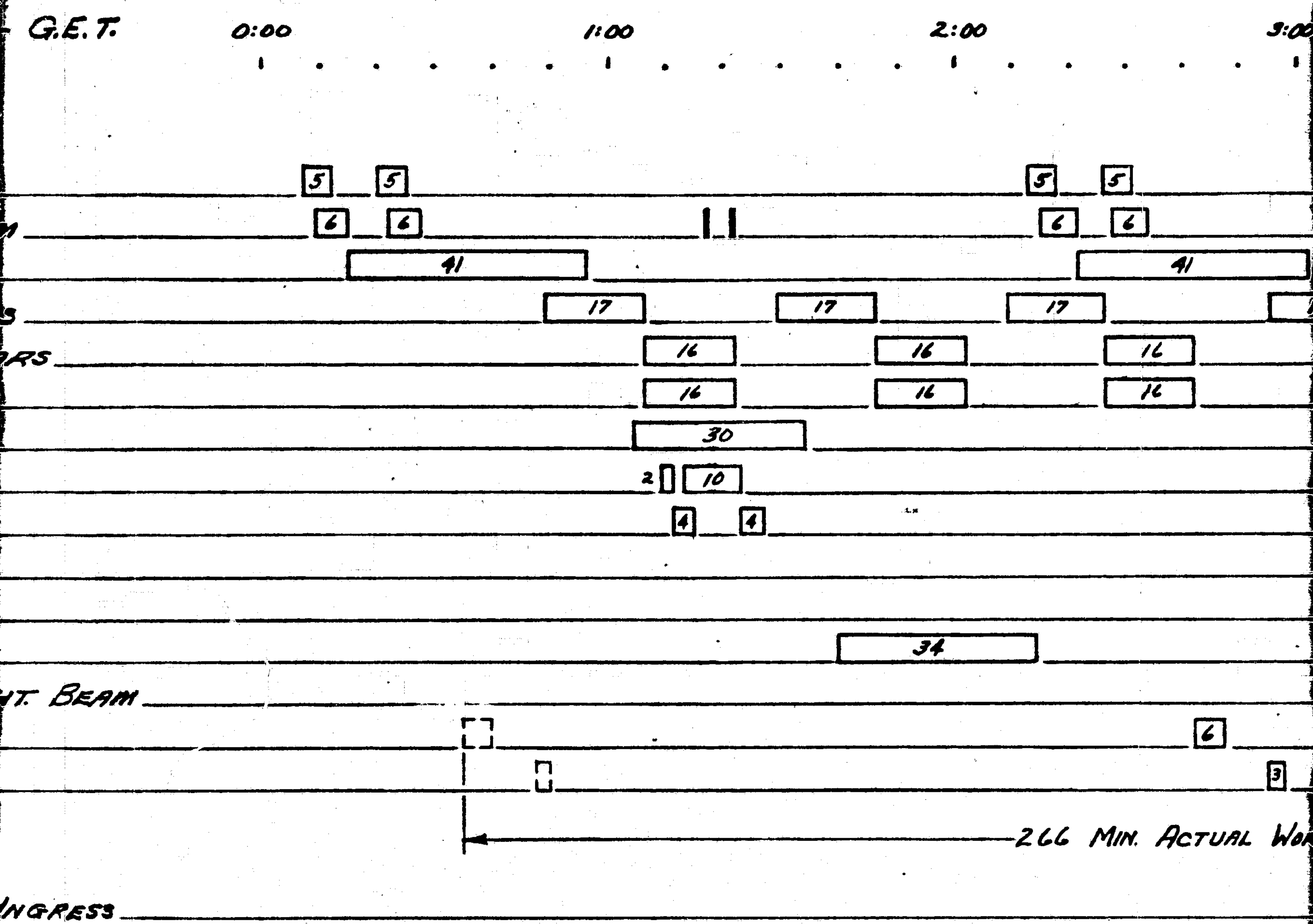
13.0 TRANSPORT CROSS BEAM ____

14.0 CONNECT ELECTRIC LINES FROM CROSS BEAM TO LONGIT. BEAM

15.0 TRANSLATE STRUCTURE ONE BAY LENGTH ____

16.0 CHECK STRUCTURAL ALIGNMENT ____

ALLOWANCE FOR ASTRONAUT EGRESS, REST, LUNCH & INGRESS __



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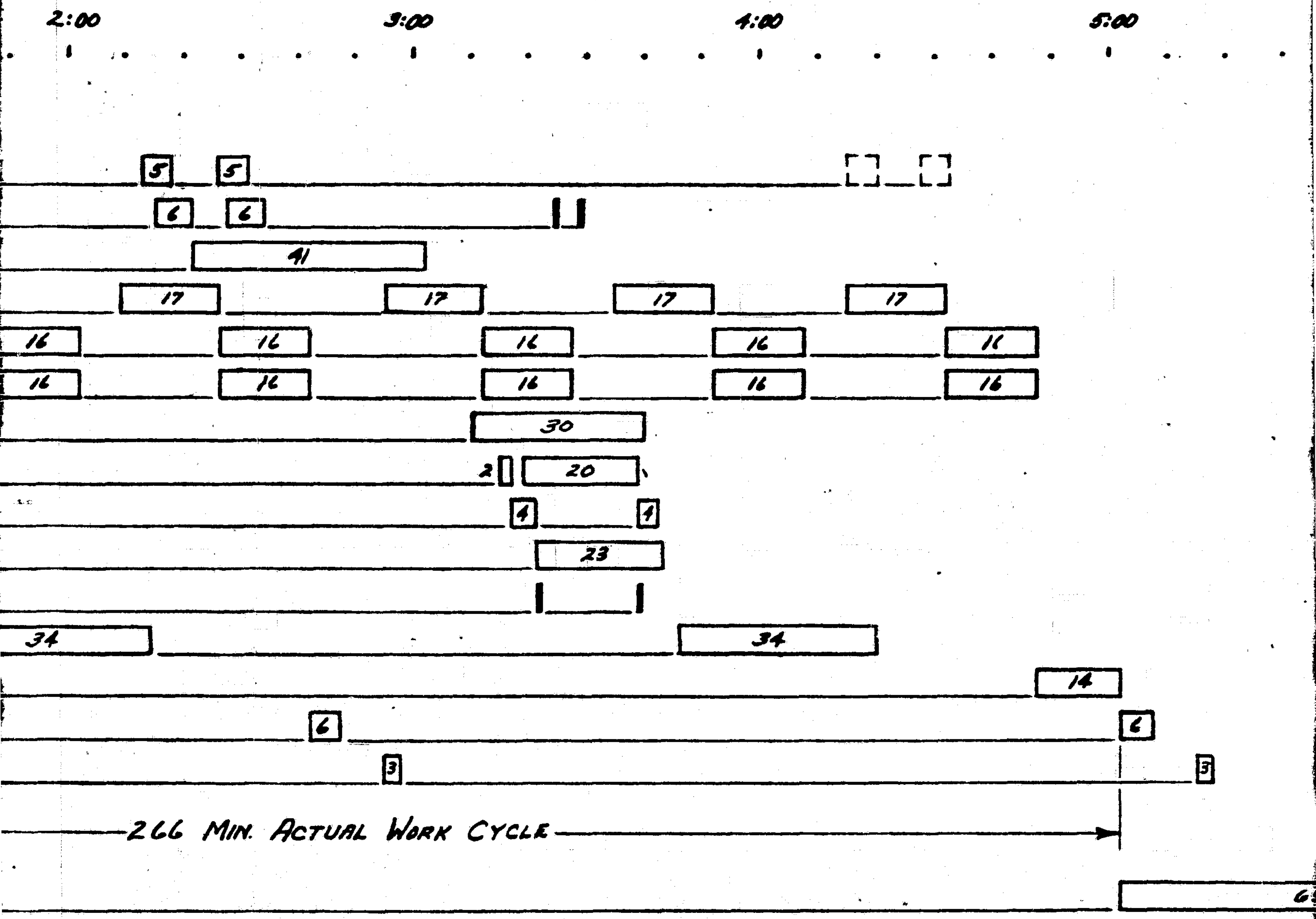

Figure 5.4-3. Representative Cycle of Re

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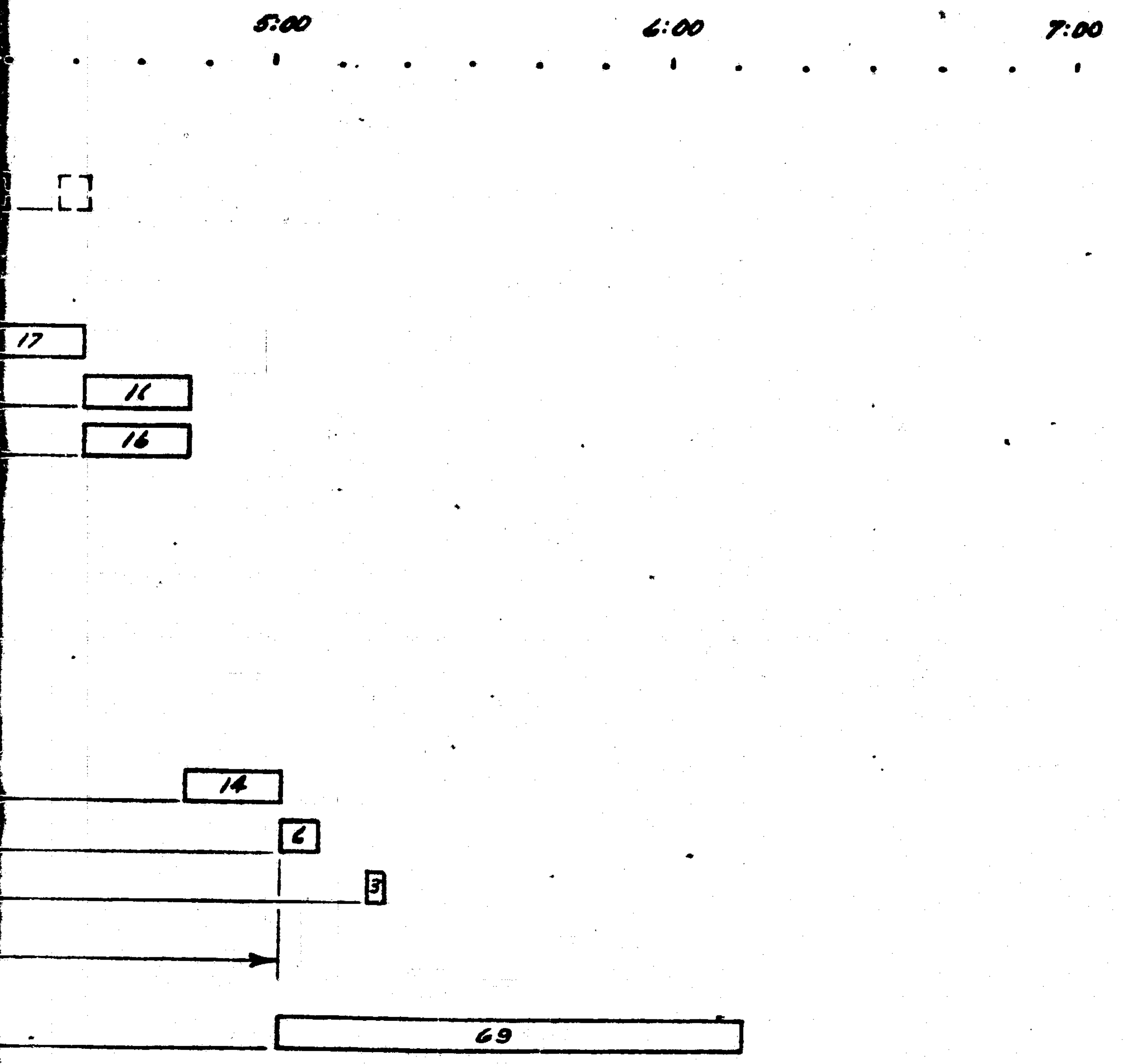

5.4-3. **Representative Cycle of Repetitive Construction Activity—First Mission**

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5.4.2 Crew Activity Scheduling Analysis

The primary driver in crew size and work schedule analysis was to accomplish the construction in minimum time, within the usual constraints of crew safety, stowage volume, weight and power limits. As a first approximation, it was assumed that minimum construction time would result in the lowest cost per flight, particularly if a need for additional kits of supplies is thus avoided.

Review of the crew workload requirements in the Construction Activity Data Sheets showed that the majority of the construction could be accomplished with a crew of two persons operating simultaneously. One crew member would be in the orbiter at the aft flight deck, and the other would be performing extravehicular activity EVA. Exceptions occur during the initial deployment of the Construction Fixture (Station No. 1) and Construction Station No. 2, and during the preparations for departure near the end of the construction period. In these cases the crew work is done from the cabin. Only one person appears to be necessary, but additional crew are available to help, and would likely be assigned active roles.

The baseline crew activity schedule developed is shown in Figure 5.4-4. It requires a crew of six, operating in teams of two persons each, three, eleven-hour work shifts per day. Except for the start-up period, one member of each team is an EVA worker and the other is the IVA operator of the RMS and other remotely controlled construction equipment. A key consideration here is that the IVA operator is also cross-trained in EVA operations and is prepared to egress on short notice to effect a rescue of the EVA worker. In order to accomplish the eight hour EVA workshift it was assumed that there would be developed an acceptable two-gas pressure suit and appropriate life support system operating at a high pressure (nominally 8 pounds per square inch). This equipment would avoid three hours of pre-breathing of 100% oxygen prior to egress. With such a capability, the EVA astronaut can theoretically accomplish eight hours of EVA (including rest periods) in an eleven hour work day, using present donning and doffing times of 1.5 hours at each end of the 8 hour work period. Reducing the donning/doffing times could reduce the work day length.

Another significant problem of crew scheduling is also solved by the high-pressure suit system. Specifically, it avoids the necessity for an IVA operator to be on 100% oxygen for 8 to 9 hours per day at full cabin pressure of 14.7 psi. This would be necessary using a single person as inside backup crew member in parallel with a 5- to 6- hour EVA shift with the EVA astronaut using the 4 psi suit currently under development for the space shuttle EVA operations. According to medical research results obtained by NASA (Reference 5-1), only 6 hours per day of continuous exposure to 100% oxygen to cabin atmospheric pressure (14.7 psi) is acceptable on a daily basis. Thus, use of the 4 psi suit would require an additional IVA backup crew member or a separate, third person per team acting as EVA crew member "buddy" on standby. Both options are undesireable. As currently designed, the construction system does not effectively utilize an additional EVA crew person for construction work. Furthermore, the orbiter cabin would become excessively crowded with the 9 crew members required to operate three shifts per day. Maintaining

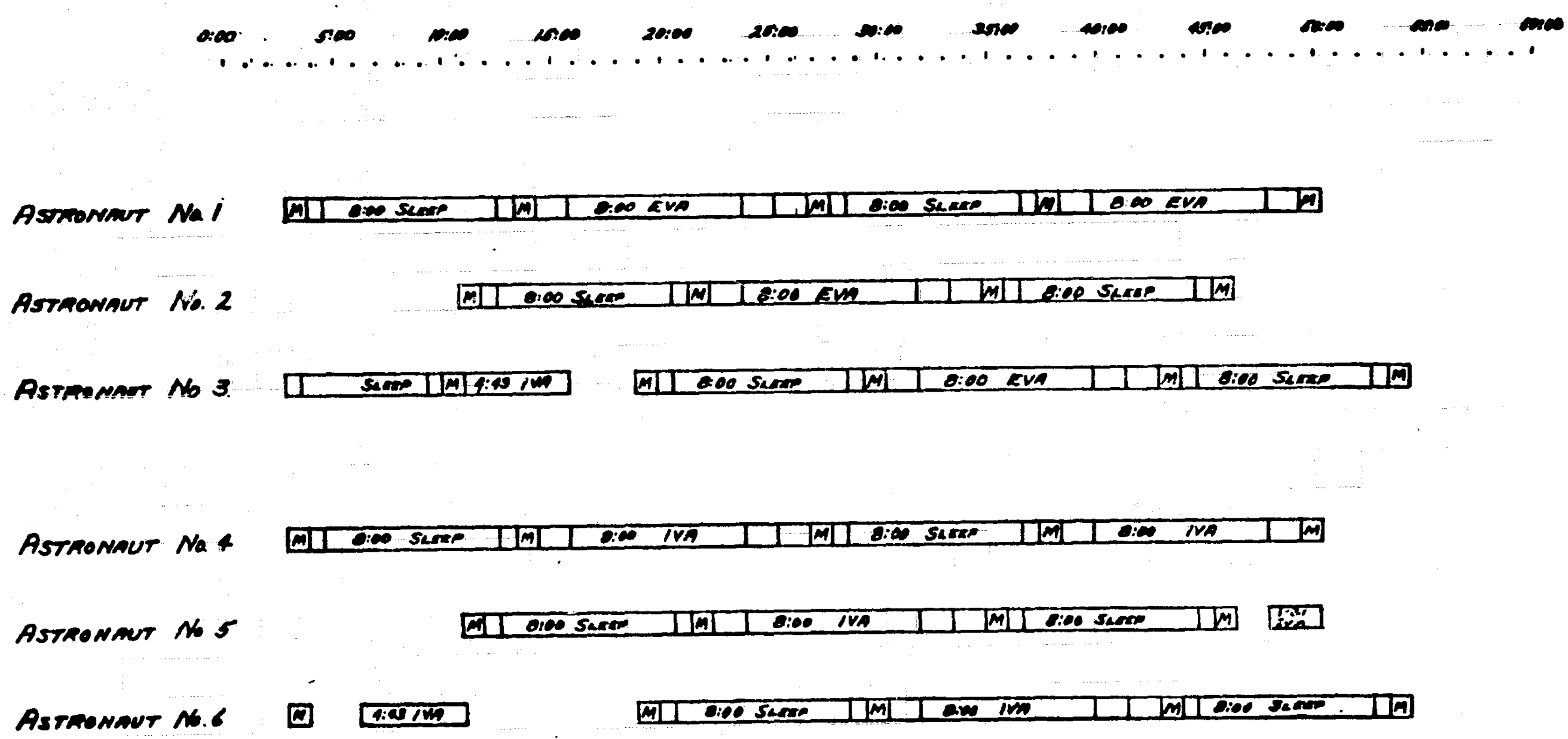


Figure 5.4-4. Baseline Crew Activity Schedule - First Mission

a crew limit of six persons, using the current 6 hour limit suit, and three hours of pre-breathing oxygen would significantly extend the required time on orbit.

Both the available EVA time per crew shift and the rest periods associated have an effect on specific construction timeline layouts. Complete analyses of alternate timelines were not developed for this study. However, an alternate schedule based on a crew of four and two shifts per day was prepared as shown in Figure 5.4-5. At the expense of longer mission time, this schedule offers advantages of less crowded crew quarters, and more utilization of the available crew. An obvious concern of the baseline schedule was that one member of the crew is utilized for only one 8 hour EVA shift during the first mission, probably after several months of expensive training.

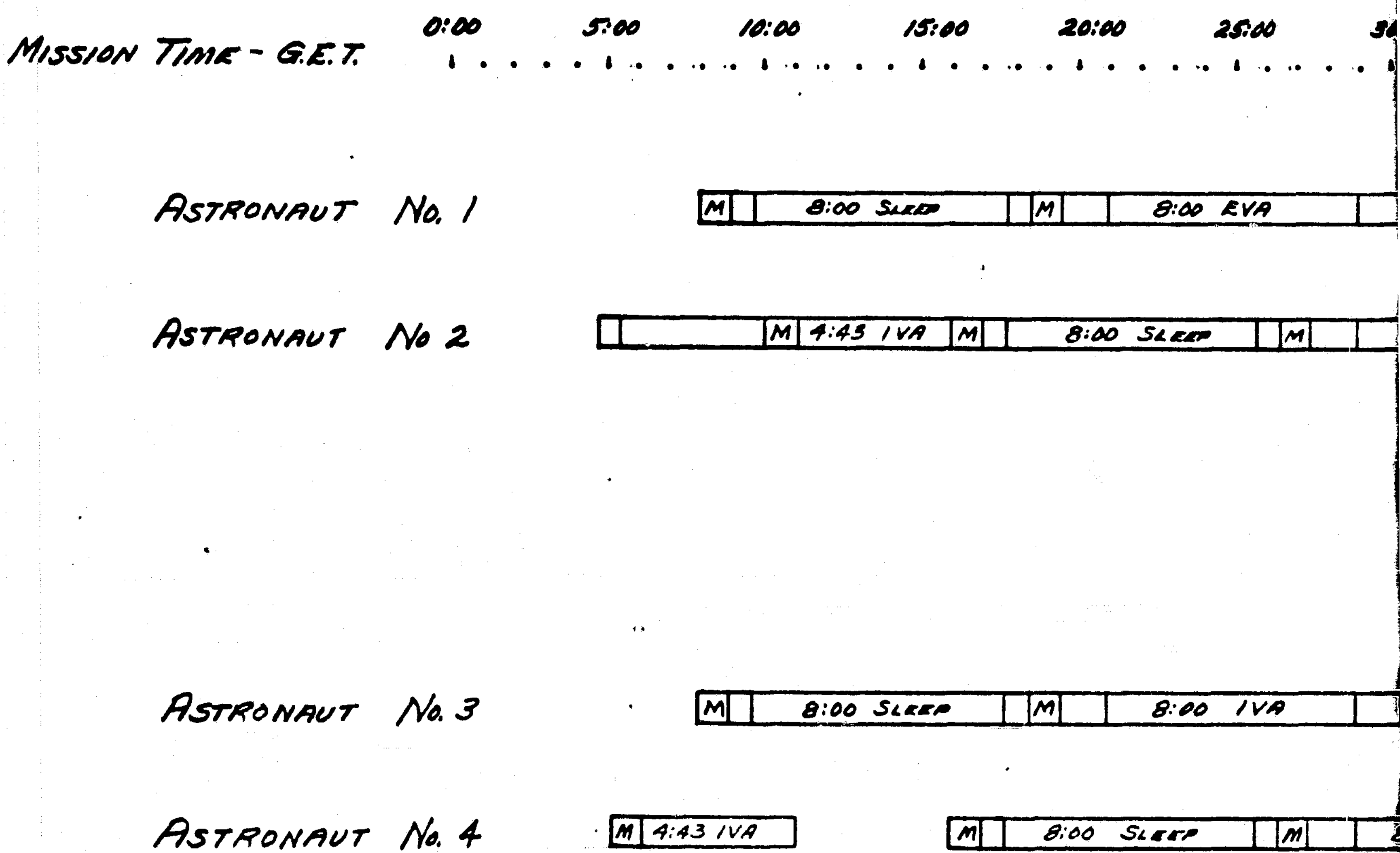
A remarkable consequence of the baseline crew utilization schedule is that the entire construction is nominally completed within approximately two days elapsed time (three days with allowance factor). The alternate schedule (Figure 5.4-5) would require about 2.7 days nominal time (4.06 days with allowance factor) depending on specific effects of crew rest periods.

In developing the crew activity schedules, NASA recommended allowances were utilized based on existing documentation (Reference 1 and Reference 2). Figure 5.4-6 shows the typical individual daily work-rest cycle adapted for a nominal 11 hour work day. The crew activity schedules provide adequate time for orbiter housekeeping functions during each shift. The scheduled duties considered for analysis are shown in Table 5.4-1, which was developed from data in Reference 2. Because of the necessity to setup each team of two crew members on staggered diurnal cycles, there is considerable free time for other crew members at the beginning and end of the construction period.

Crew rest periods during EVA are scheduled for approximately every fifty minutes and last for 10 minutes. Minor adjustments are shown in the integrated timeline to match appropriate break points in the activity. A snack period of twenty minutes is also scheduled for the middle of the eight hour period. It is presumed this will be used for a high-calorie nutrition bar inside the suit. At the beginning and end of each crew shift there is a 10 minute transport period for the astronaut to return to the airlock or move from the airlock to the work station as appropriate.

5.4.3 Lighting and TV Requirements Analysis

The general impacts of naturally available lighting and requirements for artificial lighting were investigated in significant depth during Part 1 of this construction system analysis contract study. As a result, the concepts of construction fixtures, work station designs and overall methods have been evolved toward minimum demands for power to provide artificial illumination. The systems analysis approach used in this study has been to specify a minimal set of lamps needed to perform each particular construction activity, then examine the overall integrated activity to determine additional needs or possible reductions in requirements.



MISSION TIME - G.E.T.
0:00
5:00
10:00
15:00
20:00
25:00
ASTRONAUT No. 1
M
8:00 SLEEP
M
8:00 EVA
ASTRONAUT No 2
M
4:43 IVA
M
8:00 SLEEP
M
ASTRONAUT No. 3
M
8:00 SLEEP
M
8:00 IVA
ASTRONAUT No. 4
M
4:43 IVA
M
8:00 SLEEP
M

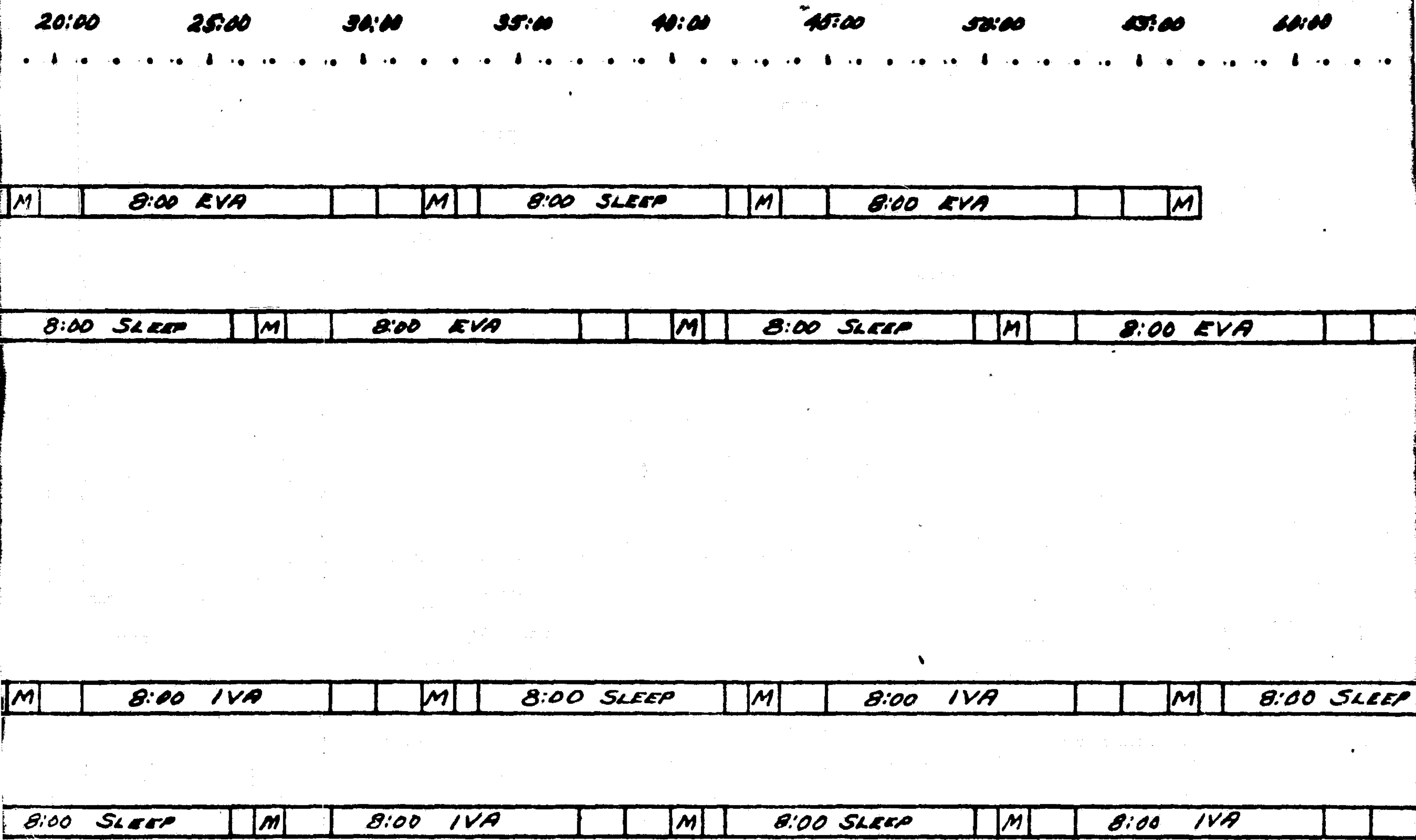


Figure 5.4-5. Alternate (4-Man) Crew

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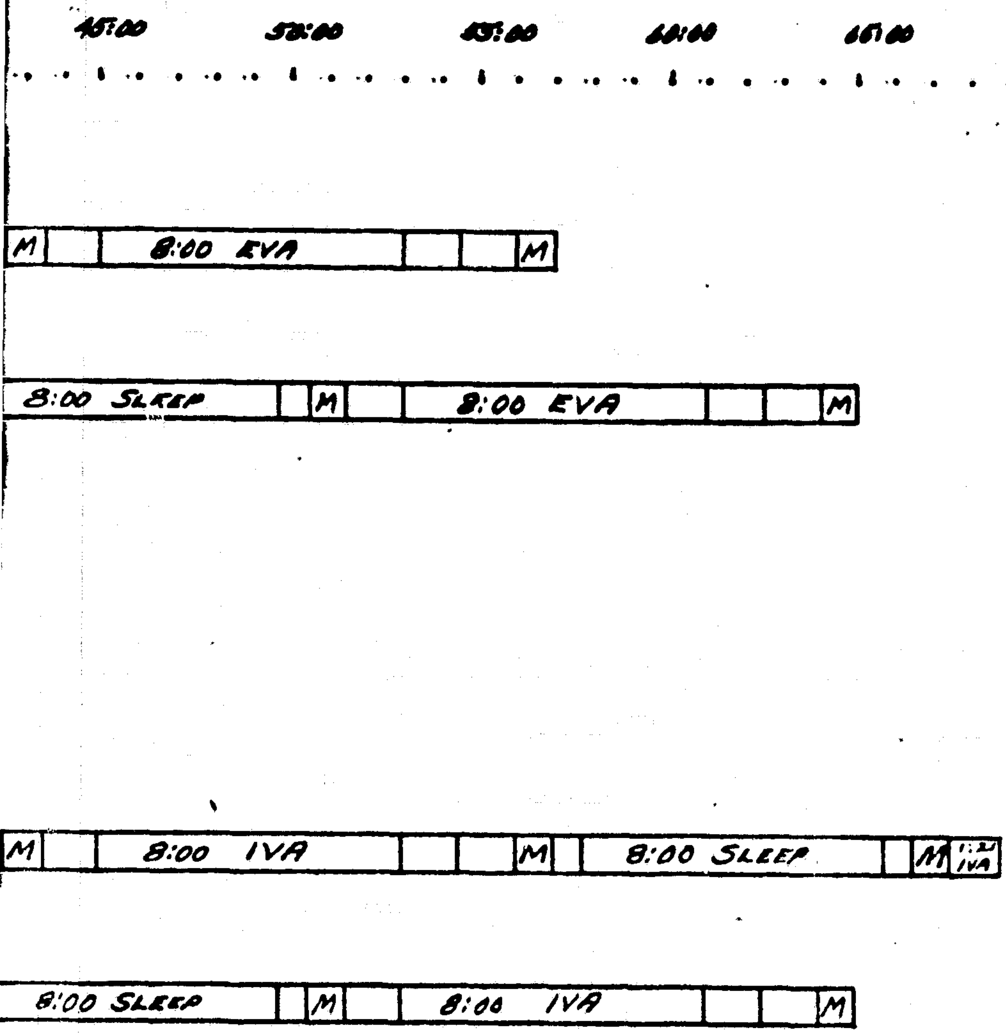

Figure 5.4-5. Alternate (4-Man) Crew Activity Schedule—First Mission

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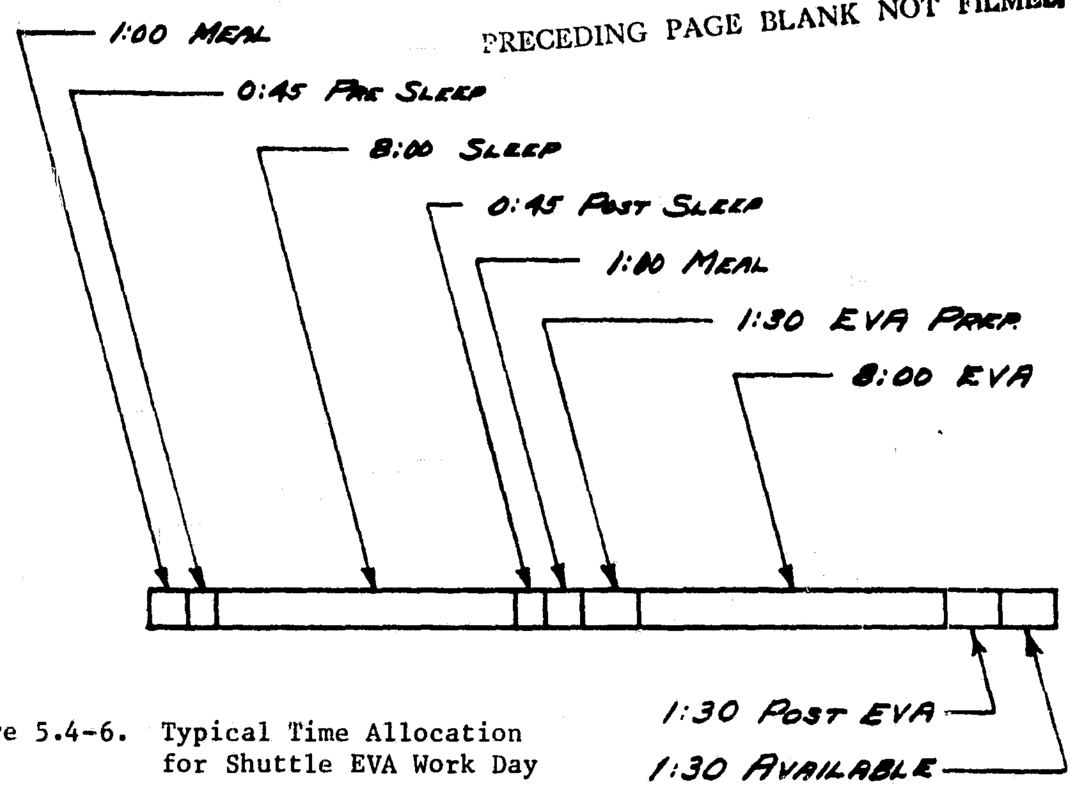

Figure 5.4-6. Typical Time Allocation for Shuttle EVA Work Day

Table 5.4-1. Orbiter Housekeeping Time Requirements

	Frequency	Duration (Min.)	Daily Time Reqmt. (Min.)
Waste Compartment Cleaning	1	15	15
Water Dump	3	5	15
CO_2 Absorber Replacement	4	5	20
Fuel Cell Purge	3	5	15
Status Report	1	15	15
GN&C Update (free drift)	3	15	45
Trash Stowage	1	15	15
Total Daily Time Requirements			140 (2 Hrs. 20 Min.)

During the development of the integrated timeline analysis the analyst attempted to keep a mental picture of which lamps and TV cameras were called for by the specific combinations of activities and to evaluate whether each lamp or camera was useful or redundant. The total power demand for lighting and TV was then calculated. The calculations are conservative, in that no account was taken of daylight versus dark side operations. It was felt this condition would represent the most practical operational condition, avoiding complexities of sensors and crew workload concerns for transitions from light side to dark side of orbit or vice versa. In fact, some alleviation of power peaks could be accomplished (if necessary) by turning off those un-needed work station lamps which are compatible with such frequent cycling. However, frequent on-off cycling of lights in the orbiter payload bay is undesireable. The integration analysis assumes that different numbers of payload bay lamps are used during the construction period in a consciously selective manner, according to expected need. For example, the lamp on the forward bulkhead is initially called for to aid observation of the handling of the construction fixture and its installation onto the docking port. Additional lamps are turned on as equipment is removed from the bay, both to provide direct illumination of the key surfaces of the components and to provide location information by means of background contrast, utilizing available open spaces between cargo items (to be determined later). Eventually, the number in use is reduced to two in the aft portion of the bay, where the crossbeams and transverse beams are fabricated. During stowage of equipment for the return trip all 6 of the payload bay lamps in the side walls will probably be used again.

Several types of small marker lamps, "running lights" and crew-held portable lamps were not specifically included in the analyses of power. It was assumed that their power demands would be small compared to the uncertainties of total power requirements. Therefore, specific mention or inclusion would not contribute greatly to overall solution of the problem.

It was considered that the construction fixture needs several types of lamps at the 100 to 200 watt level to illuminate beam positioning and joining operations. These would be selectively used according to need. Usually, not more than 200 watts would be required.

For the astronaut EVA work station (modified cherry picker and maneuvering arm), it was assumed that three 60-watt lamps would be available as needed to illuminate key work areas. This is in conformance with MRWS Open Cherry Picker design concepts proposed during Grumman studies. Two 100 watt lamps were assumed for illumination of the output area of the beam builder machine where attachment ports are also installed.

Television cameras of the same general type and power demand as planned for the RMS were identified for use with the beam builder/attachment port installation area, and various places on the construction fixtures permitting observation of EVA and aiding transportation of beams on observation of equipment. Most of these would incorporate a tilt and pan capability, but the capability is not always needed.

Figure 5.4-7 summarizes the major types and locations of lights and TV camera installations for the first mission.

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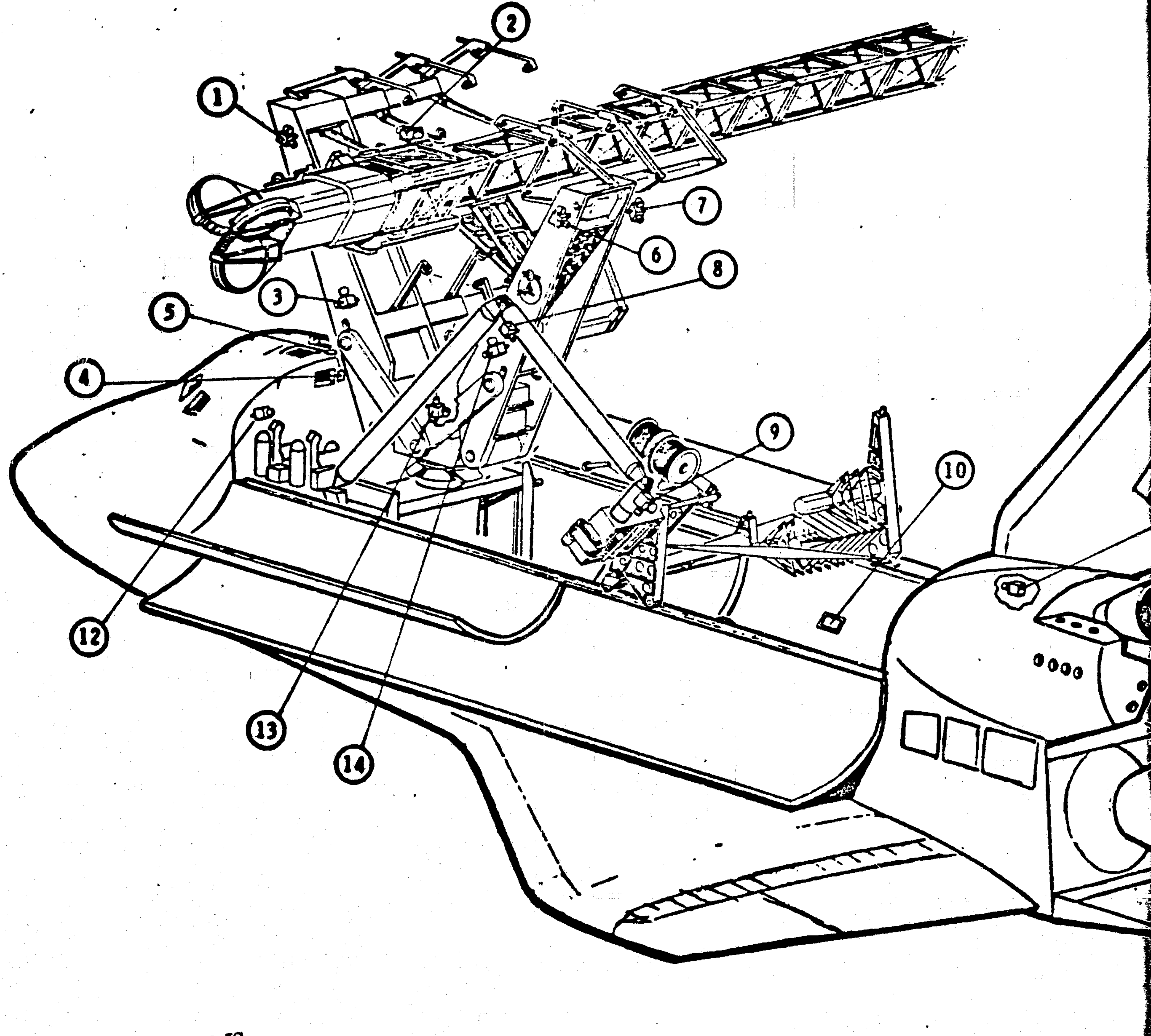
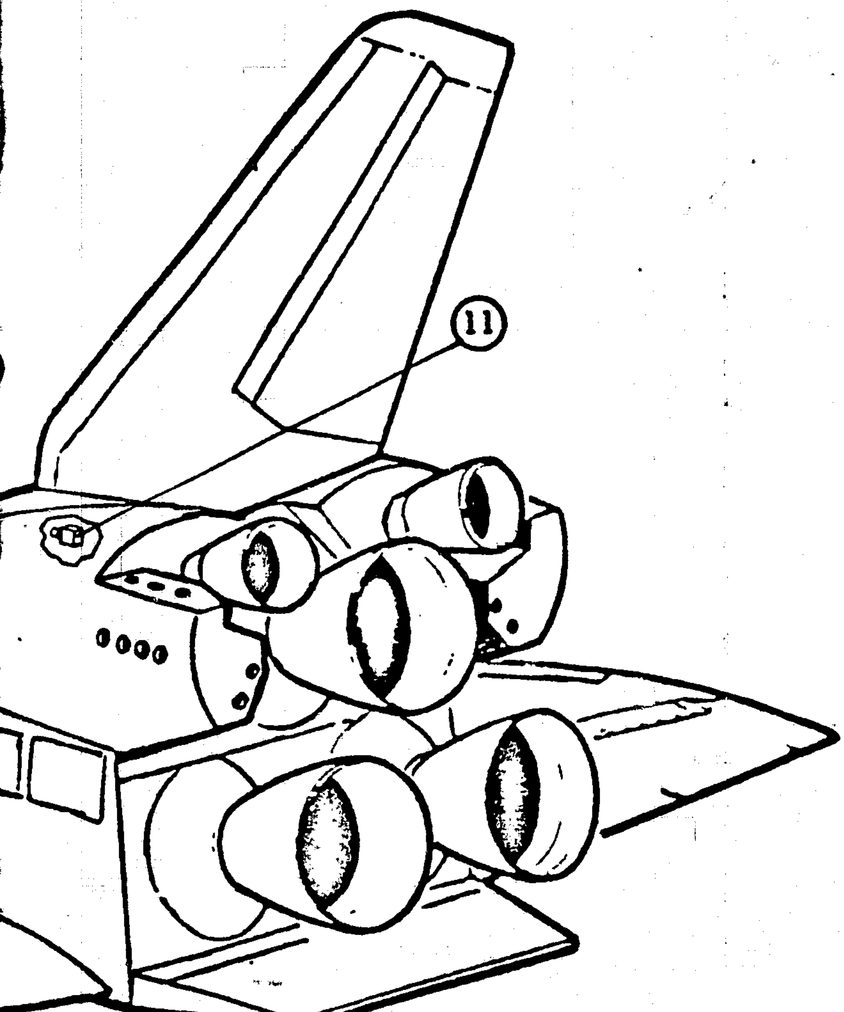


LIGHTS A



ITEM NO.	DESCRIPTION—CHARACTERISTICS/USA
(1)	ONE INCANDESCENT FLOODLAMP AND TV CAMERA FI TOGETHER ON TILT/PAN MOUNT. LOCATION—YOKE CONSTRUCTION STATION NO. 1. PURPOSE—ASSIS PORT & PRE-POSITIONING OF FORWARD TRANSVERS AND CROSSBEAMS, GENERAL ASSEMBLY AND STOWAG ASTRONAUT OBSERVATION (SAFETY AND PUBLIC RE
(2)	TWO INCANDESCENT LAMPS, ONE FIXED ON EACH S CAMERA. SET IS MOUNTED ON TILT/PAN MECHANIS LOCATION—NEAR FABRICATION END OF BEAM BUIL MACHINE. PURPOSE—OBSERVE BEAM STRAIGHTNES QUALITY, INSTALLATION OF ATTACHMENT PORTS. ASSIST HANDLING OF CROSSBEAMS AND TRANSVERS IN CONSTRUCTION STATION NO. 2 (RELOCATED WI BUILDER MACHINE). BEAM FOCUSING IS DESIRAB OBSERVE MAXIMUM POSSIBLE LENGTH OF FABRICAT
(3)	ONE LAMP AND TV UNIT SIMILAR TO (1).
(4)	ONE ORBITER PAYLOAD BAY LAMP, METAL HALIDE (STANDARD ITEM). LOCATION—FORWARD BULKHEAD ORBITER PAYLOAD BAY, BETWEEN WINDOWS. PURP (FOR CONSTRUCTION)—ASSIST HANDLING OF CONST STATION NO. 1 FROM PAYLOAD BAY STOWAGE TO D PORT. ASSIST EVA INGRESS, EGRESS.
(5)	ONE ORBITER DOCKING LAMP (STANDARD). LOCAT BETWEEN DOCKING WINDOWS ON UPPER SURFACE OF FIXED, POINTING UPWARD. PURPOSE (FOR CONSTR ASSIST HANDLING OF CONSTRUCTION STATION NO. STOWAGE TO DOCKING. ASSIST ORBITER SEPARAT END OF CONSTRUCTION.
(6)	ONE LAMP AND TV UNIT SIMILAR TO (1). PURPOS SIMILAR TO (1), BUT ALSO INCLUDES OBSERVING AND ACTIVITY AT CONSTRUCTION STATION NO. 2, STOWAGE FOR RETURN.
(7)	ONE LAMP AND TV UNIT SIMILAR TO (1). PURPOS SIMILAR TO (1), WITH SPECIAL EMPHASIS ON SET STOWAGE OF CONSTRUCTION STATION NO. 2; COVER BOARD SIDE BLIND SPOTS.

NOTES

(a) ITEMS (1), (3), (6), AND (8) MAY ALSO ASSIST OBS
(b) LAMPS ON ORBITER AND CONSTRUCTION FIXTURE NO. 1
(c) MMU OR/AND EVA SUIT WILL HAVE WORKLIGHTS AND NAV
(d) RUNNING LIGHTS AND BEACON FOR RENDEZVOUS NOT SHO

2 FOLDOUT FRAME

Figure 5.4-7. Lighting a

LIGHTS AND TV CAMERAS FOR CONSTRUCTION—FIRST MISSION

ITEM NO.	DESCRIPTION—CHARACTERISTICS/USAGE	PEAK POWER	ITEM NO.	DESCRIPTION—CHA
(1)	ONE INCANDESCENT FLOODLAMP AND TV CAMERA FIXED TOGETHER ON TILT/PAN MOUNT. LOCATION—YOKE OF CONSTRUCTION STATION NO. 1. PURPOSE—ASSIST TRANSPORT & PRE-POSITIONING OF FORWARD TRANSVERSE BEAMS AND CROSSBEAMS, GENERAL ASSEMBLY AND STOWAGE, EVA ASTRONAUT OBSERVATION (SAFETY AND PUBLIC RECORD).	0.247	(8)	ONE TV CAMERA WITH TILT RMS ELBOW (STANDARD ITEM TION—ASSIST IN HANDLING SETUP, CONSTRUCTION, STO
(2)	TWO INCANDESCENT LAMPS, ONE FIXED ON EACH SIDE OF TV CAMERA. SET IS MOUNTED ON TILT/PAN MECHANISM. LOCATION—NEAR FABRICATION END OF BEAM BUILDER MACHINE. PURPOSE—OBSERVE BEAM STRAIGHTNESS AND QUALITY, INSTALLATION OF ATTACHMENT PORTS. ALSO, ASSIST HANDLING OF CROSSBEAMS AND TRANSVERSE BEAMS IN CONSTRUCTION STATION NO. 2 (RELOCATED WITH BEAM BUILDER MACHINE). BEAM FOCUSING IS DESIRABLE TO OBSERVE MAXIMUM POSSIBLE LENGTH OF FABRICATED BEAM.	0.247	(9)	ONE LAMP AND TV CAMERA F PAN MOUNT. LOCATION—RM BUT NEW MOUNT). PURPOSE ULES, TRANSPORTING THEM THEM TO PERFORM SETUP, C
(3)	ONE LAMP AND TV UNIT SIMILAR TO (1).	0.247	(10)	SIX METAL HALIDE LAMPS O ITEMS). LOCATION—SIDE BAY; ONE OF SIX ILLUSTRA TION—BACKGROUND FOR EXT STRUCTION EQUIPMENT, SET NO. 2 AND EVA INSPECTION DIFFUSERS OR BLINDS MAY CAMERAS FROM DIRECT VIEW
(4)	ONE ORBITER PAYLOAD BAY LAMP, METAL HALIDE TYPE (STANDARD ITEM). LOCATION—FORWARD BULKHEAD OF ORBITER PAYLOAD BAY, BETWEEN WINDOWS. PURPOSE—(FOR CONSTRUCTION)—ASSIST HANDLING OF CONSTRUCTION STATION NO. 1 FROM PAYLOAD BAY STOWAGE TO DOCKING PORT. ASSIST EVA INGRESS, EGRESS.	0.200	(11)	ONE TV CAMERA UNIT (STAN TILT & PAN MOUNT. LOCAT ORBITER PAYLOAD BAY. PU ASSIST IN SETUP OF CONST EXTRACTION AND STOWAGE O TRANSPORT OF BEAMS.
(5)	ONE ORBITER DOCKING LAMP (STANDARD). LOCATION—BETWEEN DOCKING WINDOWS ON UPPER SURFACE OF CABIN. FIXED, POINTING UPWARD. PURPOSE (FOR CONSTRUCTION)—ASSIST HANDLING OF CONSTRUCTION STATION NO. 1 FROM STOWAGE TO DOCKING. ASSIST ORBITER SEPARATION AT END OF CONSTRUCTION.	0.200	(12)	ONE TV CAMERA UNIT, SIMI FOWARD BULKHEAD OF ORBIT ASSIST SETUP OF CONSTRUC PORT OF FORWARD TRANSVER WATCH. MAJOR AID IN PRE WITH STRUCTURE.
(6)	ONE LAMP AND TV UNIT SIMILAR TO (1). PURPOSE—SIMILAR TO (1), BUT ALSO INCLUDES OBSERVING SETUP AND ACTIVITY AT CONSTRUCTION STATION NO. 2, CARGO STOWAGE FOR RETURN.	0.247	(13)	ONE LAMP & TV UNIT SIMIL LOWER CROSS BRIDGE OF BU PURPOSE—ASSIST IN RELOC REMOVAL OF CENTRAL PORTI
(7)	ONE LAMP AND TV UNIT SIMILAR TO (1). PURPOSE—SIMILAR TO (1), WITH SPECIAL EMPHASIS ON SETUP AND STOWAGE OF CONSTRUCTION STATION NO. 2; COVERS STARBOARD SIDE BLIND SPOTS.	0.247	(14)	ONE LAMP & TV UNIT SIMIL SIMILAR TO (6), ILLUMINA HANDLING AND PRE-POSITIO

NOTES

(a) ITEMS (1), (3), (6), AND (8) MAY ALSO ASSIST OBSERVATION OF TRANSLATION OF STRUCTURAL ASSY AND DEPLOYM
(b) LAMPS ON ORBITER AND CONSTRUCTION FIXTURE NO. 1 ARE ALSO USEFUL FOR SECOND AND THIRD MISSIONS.
(c) MMU OR/AND EVA SUIT WILL HAVE WORKLIGHTS AND NAVIGATION LIGHTS. MODIFIED CHERRY PICKER (NOT VISIBLE) H
(d) RUNNING LIGHTS AND BEACON FOR RENDEZVOUS NOT SHOWN.

Figure 5.4-7. Lighting and TV Camera Locations for Construction—First Mission

LIGHTS AND TV CAMERAS FOR CONSTRUCTION—FIRST MISSION

...ISTICS/USAGE	PEAK POWER
CAMERA FIXED TION—YOKE OF OSE—ASSIST TRANS- TRANSVERSE BEAMS AND STOWAGE, EVA PUBLIC RECORD).	0.247
ON EACH SIDE OF TV AN MECHANISM. BEAM BUILDER TRAIGHTNESS AND NT PORTS. ALSO, TRANSVERSE BEAMS LOCATED WITH BEAM IS DESIRABLE TO F FABRICATED BEAM.	0.247
I).	0.247
AL HALIDE TYPE RD BULKHEAD OF OWS. PURPOSE— NG OF CONSTRUCTION OWAGE TO DOCKING	0.200
D). LOCATION— SURFACE OF CABIN. (FOR CONSTRUCTION)— TATION NO. 1 FROM ER SEPARATION AT	0.200
I). PURPOSE— OBSERVING SETUP ON NO. 2, CARGO	0.247
). PURPOSE— SIS ON SETUP AND . 2; COVERS STAR-	0.247

ITEM NO.	DESCRIPTION—CHARACTERISTICS/USAGE	PEAK POWER
(8)	ONE TV CAMERA WITH TILT AND PAN MOUNT. LOCATION—RMS ELBOW (STANDARD ITEM). PURPOSE (FOR CONSTRUCTION—ASSIST IN HANDLING BEAMS, OTHER MODULES IN SETUP, CONSTRUCTION, STOWAGE.	0.047
(9)	ONE LAMP AND TV CAMERA FIXED TOGETHER ON TILT AND PAN MOUNT. LOCATION—RMS WRIST (STANDARD LOCATION, BUT NEW MOUNT). PURPOSE—ASSIST IN GRAPPLING MODULES, TRANSPORTING THEM AND POSITIONING OR BERTHING THEM TO PERFORM SETUP, CONSTRUCTION, AND STOWAGE.	0.220
(10)	SIX METAL HALIDE LAMPS OF 0.200 kW EACH (STANDARD ITEMS). LOCATION—SIDE WALLS OF ORBITER PAYLOAD BAY; ONE OF SIX ILLUSTRATED. PURPOSE (FOR CONSTRUCTION—BACKGROUND FOR EXTRACTING AND STOWING OF CONSTRUCTION EQUIPMENT, SETUP OF CONSTRUCTION STATION NO. 2 AND EVA INSPECTION. (NOTE: SOME SPECIAL DIFFUSERS OR BLINDS MAY BE NEEDED TO PROTECT TV CAMERAS FROM DIRECT VIEW OF LAMPS.	1.200
(11)	ONE TV CAMERA UNIT (STANDARD ORBITER ITEM) WITH TILT & PAN MOUNT. LOCATION—AFT BULKHEAD OF ORBITER PAYLOAD BAY. PURPOSE (FOR CONSTRUCTION)—ASSIST IN SETUP OF CONSTRUCTION STATION NO. 2, EXTRACTION AND STOWAGE OF CONSTRUCTION EQUIPMENT, TRANSPORT OF BEAMS.	0.047
(12)	ONE TV CAMERA UNIT, SIMILAR TO (11) BUT LOCATED ON FOWARD BULKHEAD OF ORBITER PAYLOAD BAY. PURPOSE—ASSIST SETUP OF CONSTRUCTION STATION NO. 1, TRANSPORT OF FORWARD TRANSVERSE BEAMS AND EVA SAFETY WATCH. MAJOR AID IN PREVENTING RMS ARM COLLISION WITH STRUCTURE.	0.247
(13)	ONE LAMP & TV UNIT SIMILAR TO (1) BUT LOCATED ON LOWER CROSS BRIDGE OF BUILDING FIXTURE YOKE. PURPOSE—ASSIST IN RELOCATION OF BEAM BUILDER, REMOVAL OF CENTRAL PORTION OF CONSTR. FIXTURE NO. 1	0.247
(14)	ONE LAMP & TV UNIT SIMILAR TO (1). PURPOSE—SIMILAR TO (6), ILLUMINATES AFT TRANSVERSE BEAM HANDLING AND PRE-POSITIONING BY RMS.	0.247

ASSIST OBSERVATION OF TRANSLATION OF STRUCTURAL ASSY AND DEPLOYMENT OF LIBRATION DAMPER.
URE NO. 1 ARE ALSO USEFUL FOR SECOND AND THIRD MISSIONS.
ITS AND NAVIGATION LIGHTS. MODIFIED CHERRY PICKER (NOT VISIBLE) HAS THREE 60-W LAMPS.
US NOT SHOWN.

FOLDOUT FRAME

4

Lighting and TV Camera Locations for Construction—First Mission

5.4.4 Power Demand Analysis

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The construction activity logic, construction support equipment, and detailed timeline development were designed to avoid gross and obvious power demand peaking. For example, only one beam builder machine is supplied, and consideration was given to minimizing use of lights. In addition, the basic concept of the primary construction fixture minimized the work space volume and thus kept lighting and transport demands low. Nevertheless, there was continuing concern that power demands might exceed the nominal payload power capacity of the Shuttle orbiter. This power capacity is basically limited by heat rejection capability of the orbiter radiators to a maximum of 7 kW continuously, or up to 12 kW for 15 minutes every three hours. The baseline orbiter energy capacity was assumed to be 50 kWh without added cryogenic tanks. Additional fuel for energy can be supplied by cryogenic tanks sets, as indicated in Figure 5.4-8. For example, one extra tank set provides 840 kWh for payload energy.

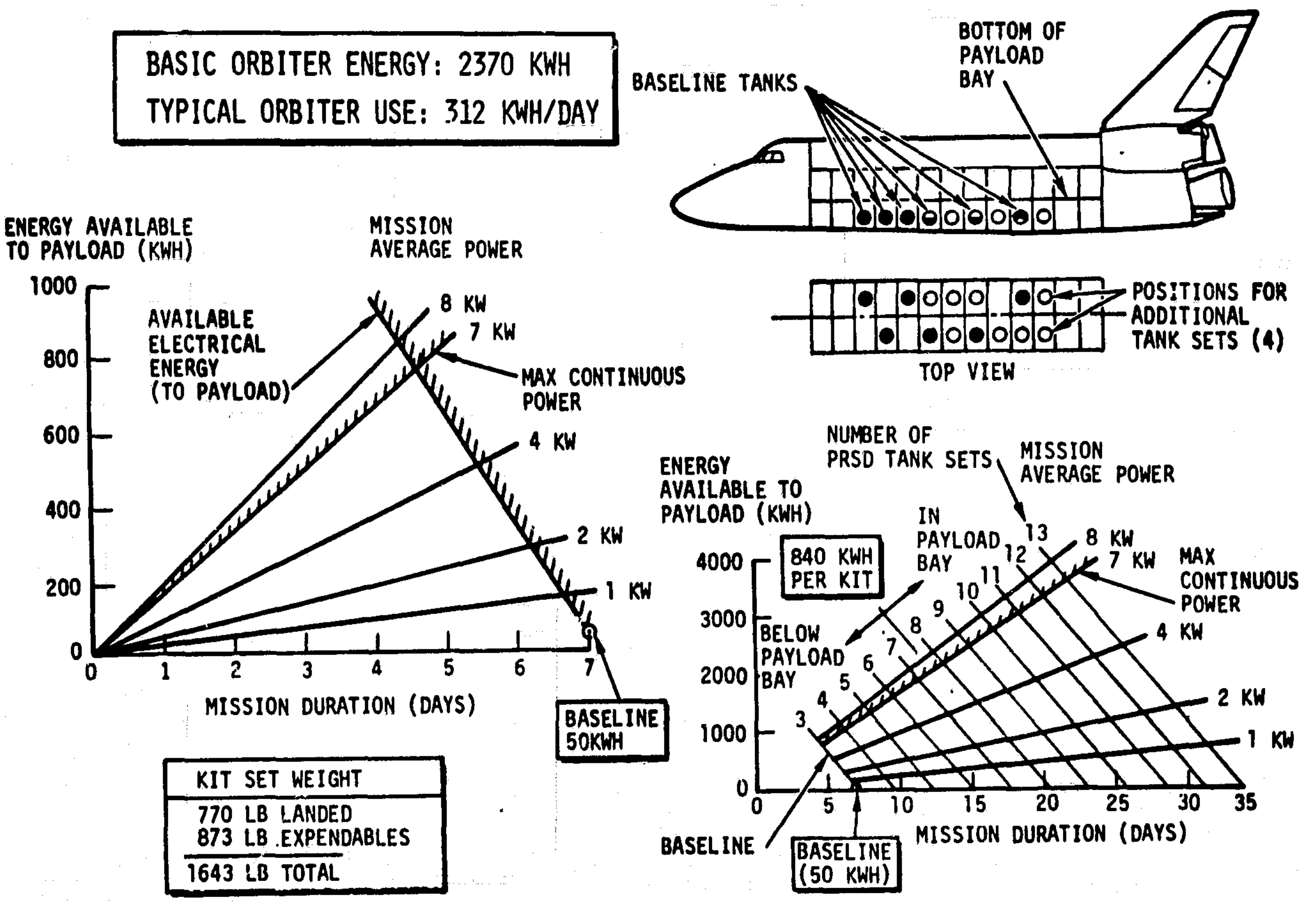


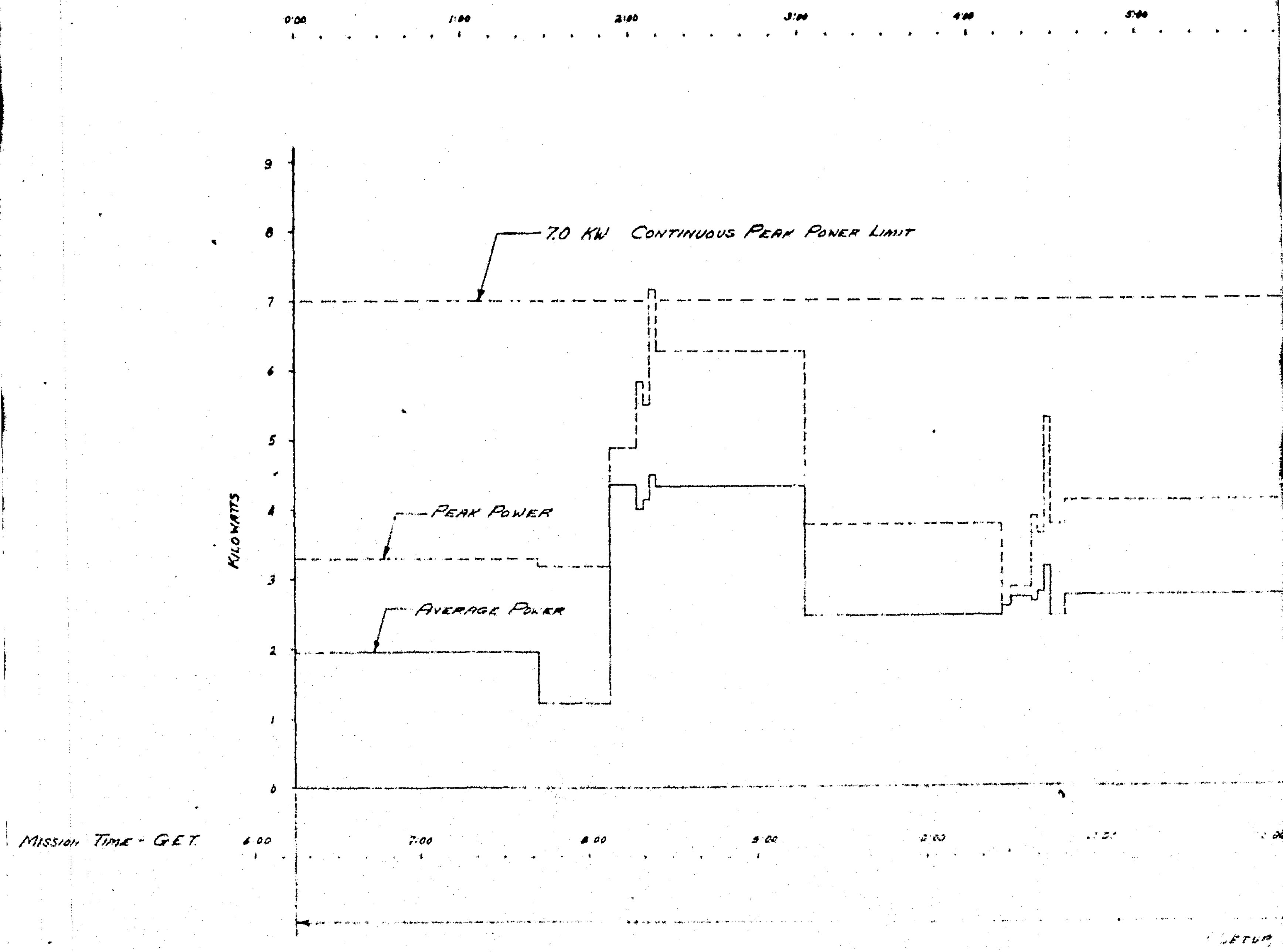
Figure 5.4-8. Payload Energy/Power Availability

It is appropriate to examine closely the basic assumptions and estimation processes used in the power and energy analyses in order to consider their future applicability to other proposed projects. Table 5.4-2 lists several key assumptions and estimating procedures used.

Table 5.4-2. Key Assumptions and Estimating Procedures for Power Demand/Energy Analysis—First Mission

1.	The beam builder machine is turned on for at least seven minutes (430 sec nominal) prior to usage for a warmup and/or checkout period, and is turned off after each beam is constructed. During the early buildup portion, power demand was conservatively estimated at 2.240 kW. Later inquiry established the demand at 1.53 kW as a conservative estimate. These magnitudes incorporate a margin for additional cap thickness of the beam used in the Rockwell design as compared to the basic beam design analyzed by General Dynamics.
2.	Lighting was provided continuously for all functions as if they were to be conducted on the dark side of orbit. Lighting levels are considered frugal, but adequate, to accomplish key assembly activities.
3.	All heaters for RMS motors, TV cameras, and other mechanisms were estimated to be operating 50 percent of the time, during which the mechanism was used on a ready-standby status.
4.	The RMS heaters, wrist TV camera, camera heater, and light were left on at all times between RMS usage, except during fabrication of the longitudinal beams.
5.	The entire analysis is success-oriented. No power allocation is specified for contingency operations. However, a design margin of 50 percent is applied to the calculated energy to account for unintentional omissions.

The power profile and energy analyses were performed in two parts, as illustrated in Figure 5.4-9. The first portion (at the left of the figure) involved the initial setup of the construction fixture, the fabrication of longitudinal beams, the fabrication of the first frame set of two transverse beams and one long crossbeam, and their assembly to the longitudinal beams. All sequences and crew rest periods were assumed as shown in Figure 5.4-2, up to the time for the first translation of the assembly. Another portion of the analysis was based on a representative, modular division of effort which is repeated five times. The power profile for this portion is at the right of Figure 5.4-9. This cycle of work involves fabrication and assembly of two consecutive sets of frames, one with a long crossbeam and one with a short crossbeam, together with the cross-brace cords installations between them and in the previous adjacent bay (Figure 5.4-2). This modular segment of repetitive work is somewhat artificial in that it does not show probable occurrences of crew rest periods or crew exchange periods. If such were included, the timelines could not be exactly repetitive since crew rest periods do not occur at precisely the same point in the sequence on every cycle. However, the inclusion of time for crew rest/exchange periods will generally tend to reduce average power levels and exposure to power peaks. The effects on average power and total energy are partially accounted for in the "representative" cycles by adding time for rest/exchange periods into



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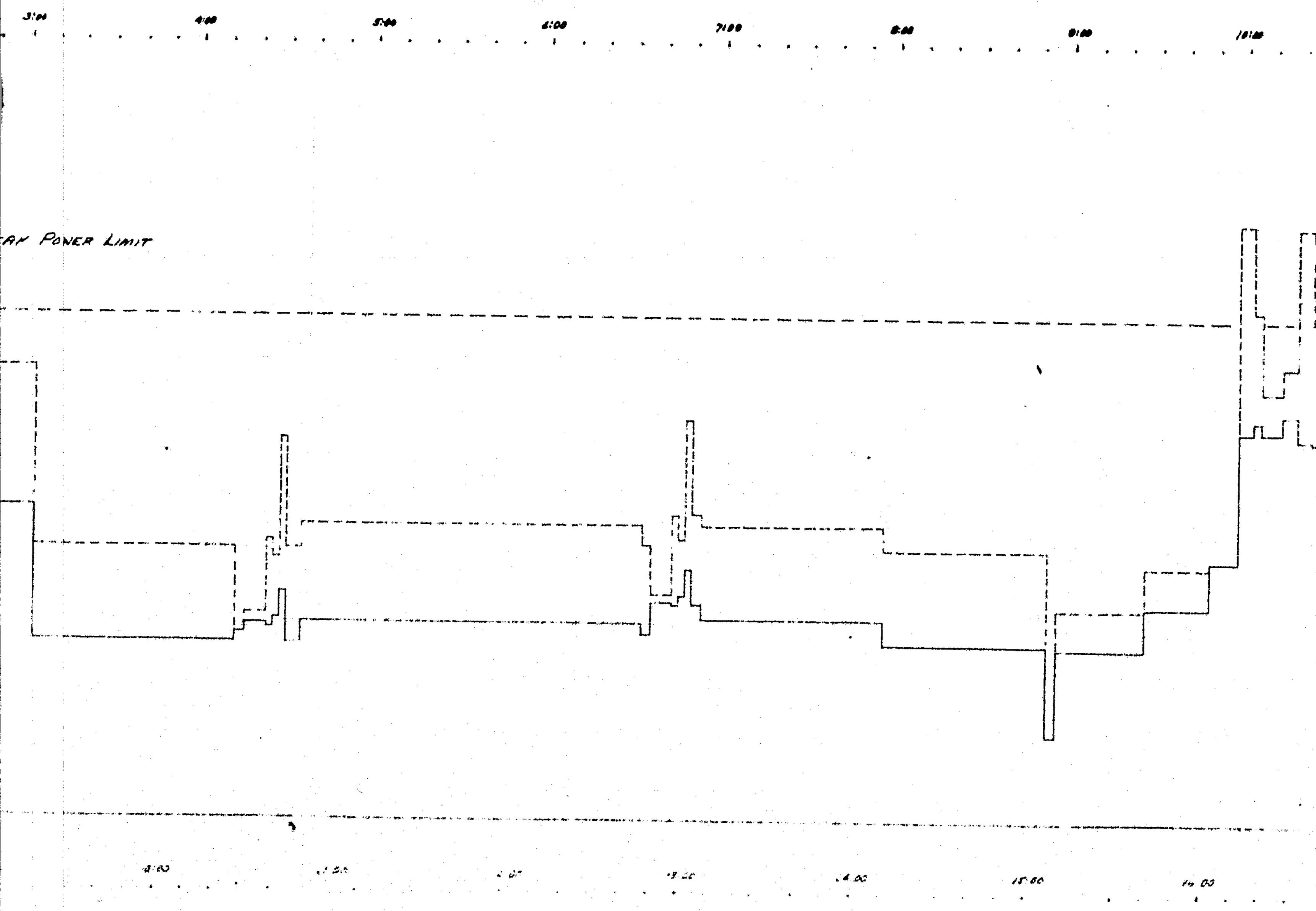

ITIAL PERIOD
(SETUP, FABRICATION OF LONGITUDINAL BEAMS
AND INITIAL FRAME SET INSTALLATION
PRIOR TO FIRST TRANSLATION OF PLATFORM)

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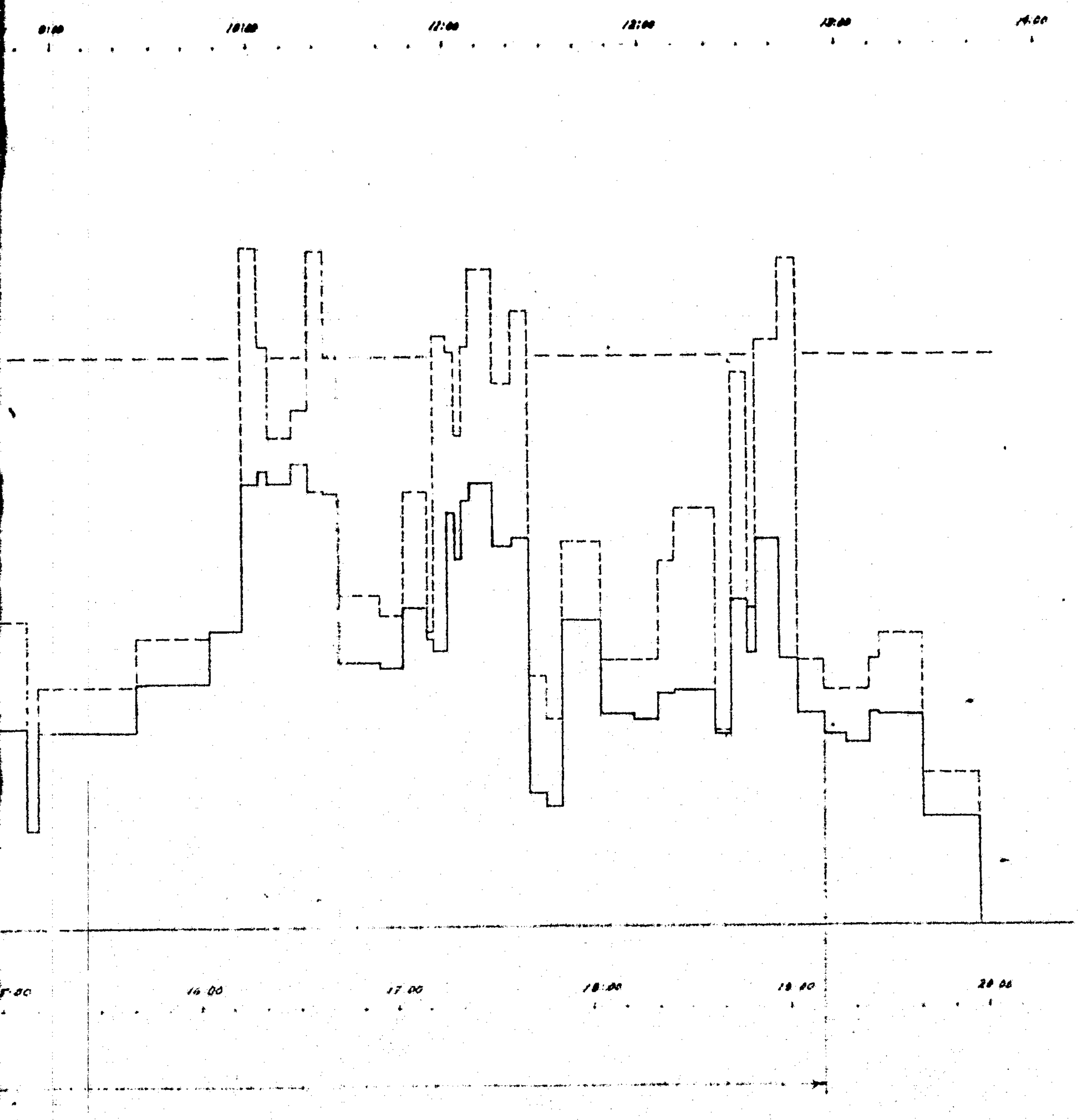

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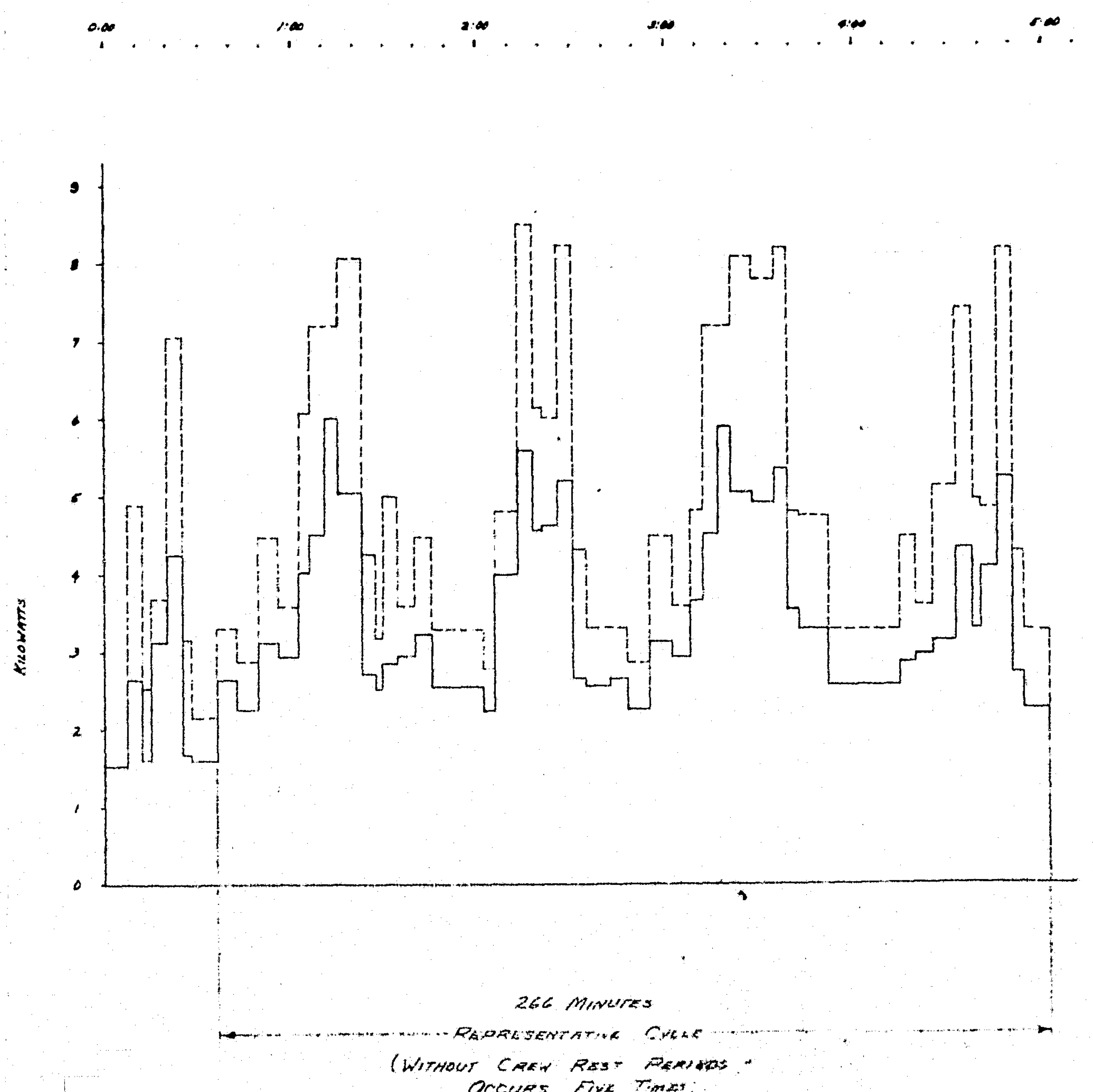

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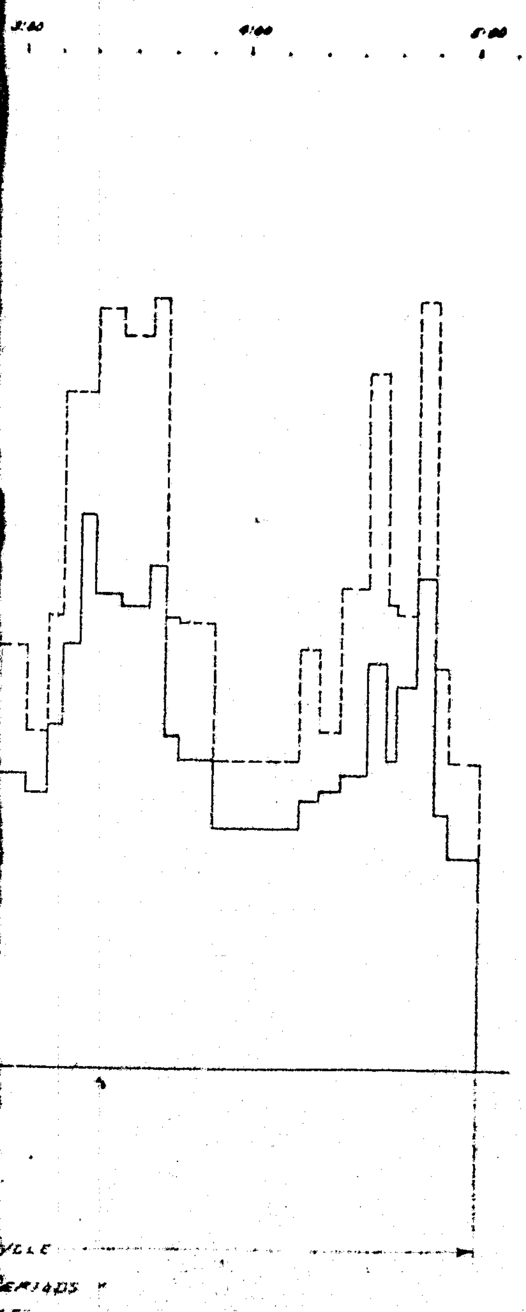

Figure 5.4-9. Power Profile for First Mission

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the calculation of overall averages. To calculate the total energy requirements for construction, these "representative cycles" were assumed to have been repeated five times, and the total added to the "initial period" analysis. A small reduction was applied to account for nonrepetitive items in the last cycle. Finally, a small segment of power and energy was defined for the activities of stowing return cargo, preparing the construction fixture, and checking it out for untended operation. The combination of these activity segments to develop a nominal (no-margin) estimate and a baseline estimate with design margin is outlined in Table 5.4-3.

Table 5.4-3. Total Energy and Average Power—First Mission

Activity Segment	Duration (hr)	Energy Required (kWh)	Average Power (kW)
• Initial activity—begin IVA, to first translation	12.93	39.11	3.02
• Repetitive activity—long and short crossbeam frames and translations, 5 cycles at 20.19 kWh and 335 minutes each; 5×20.19 = 100.95 kWh			
Adjustment for last cycle: -1.21 kWh	27.9*	99.74*	3.57*
• Shutdown activity	1.67	5.59	3.35
Nominal total energy	42.5*	144.44	3.40*
Design margin (50% of nominal)	+21.25	+72.22	+3.40
Baseline magnitudes for construction period	63.75 (2.66 days)	216.66	3.40

*Based on repetitive time and energy estimates.

The design margin for the integrated construction timeline analysis, as shown in Table 5.4-3, was arbitrarily established as 50 percent longer than the nominal time estimate. The associated power and energy margin was simply developed by assuming the nominal average power level would continue for the 50% design margin of time. This concept is consistent with the approach of rescheduling activities to avoid simultaneous use of equipment having a high power demand. Also, any unexpected problems of assembly or delays in crew scheduling would tend to extend the time without increasing peak power demands. The resulting derived baseline power and energy requirements are considered to include unintentional omissions, work interruptions due to unacceptable sun-viewing conditions, and possible delays for crew planning time. Contingencies involving mechanical or electrical repairs, spare parts exchanges, or crew entanglements, etc., are not considered in these analyses.

Foregoing considerations have primarily accounted for overall average power demands and total energy requirements. However, they did not specifically deal with exposures to peak power demand which exceed the nominal orbiter limits of 7 kW. Figure 5.4-9 shows several periods where it is possible that peak power demands might exceed 7 kW, sometimes for over 15 minutes. Since such high demands can have an undesirable effect on fuel cell life, it is expected that they would be eliminated by extending the total construction time (within the above described margin) to avoid simultaneous operations of high-powered equipment.

Typically, the peak power demands occur when beams are being transported and fabricated simultaneously. Addition of other activities at the same time, such as installing and tensioning cross-brace cords, pushes the potential peak power over the 7-kW limit. However, this exposure is only a statistical probability, since average power demands rarely exceed 6 kW. When crew rest periods are scheduled near critical power demand periods, some "natural" work period stretchout and peak leveling will be experienced.

Among the major contributors to the possibility of excessive power peaks are the electric heaters on the RMS and the orbiter lamps. In the analysis, it was assumed that most of the specially designed construction support equipment will not require electric heaters. This approach is justified on the basis of an expected low number of duty cycles and expected advancements in technology. However, should more heaters be required for some of the automatic assembly machinery, greater attention could be given to energy management to meet thermal requirements by selective on/off cycling of heaters and by more judicious design of low-power lighting systems. Based on the current results, extreme measures to reduce lighting power do not appear justified for the construction of the type of platform used as a model for this study.

5.4.5 Construction Support Equipment (CSE) Requirements

At the outset of this discussion, it is important to clarify terminology. By the term *construction support equipment* is meant those particular devices which directly and actively contribute to the processes of on-orbit construction, but are not finally incorporated into the spacecraft which remains at low earth orbit and is sent to geosynchronous orbit. In some cases, items like the modified orbiter remote manipulator system are included, even though these may be later considered as general-purpose, standard "orbiter equipment" in programmatic terms. Items involved exclusively in transportation (e.g., cradles, pallets) are not included. In fact, a hard and precise definition is not easy to formulate. For example, the main yoke of the primary construction fixture is assumed to remain on the constructed spacecraft during its life at low earth orbit, but would not be sent to geosynchronous orbit.

Figures 5.4-10 through 5.4-13 illustrate the identified CSE and describe the key characteristics and usages for the first mission.

A major point to be brought out here is that these space construction equipment items significantly determine the crew productivity, just as does production machinery in a factory. They also significantly affect the time on orbit, the power demands, and the cost of construction. These equipment

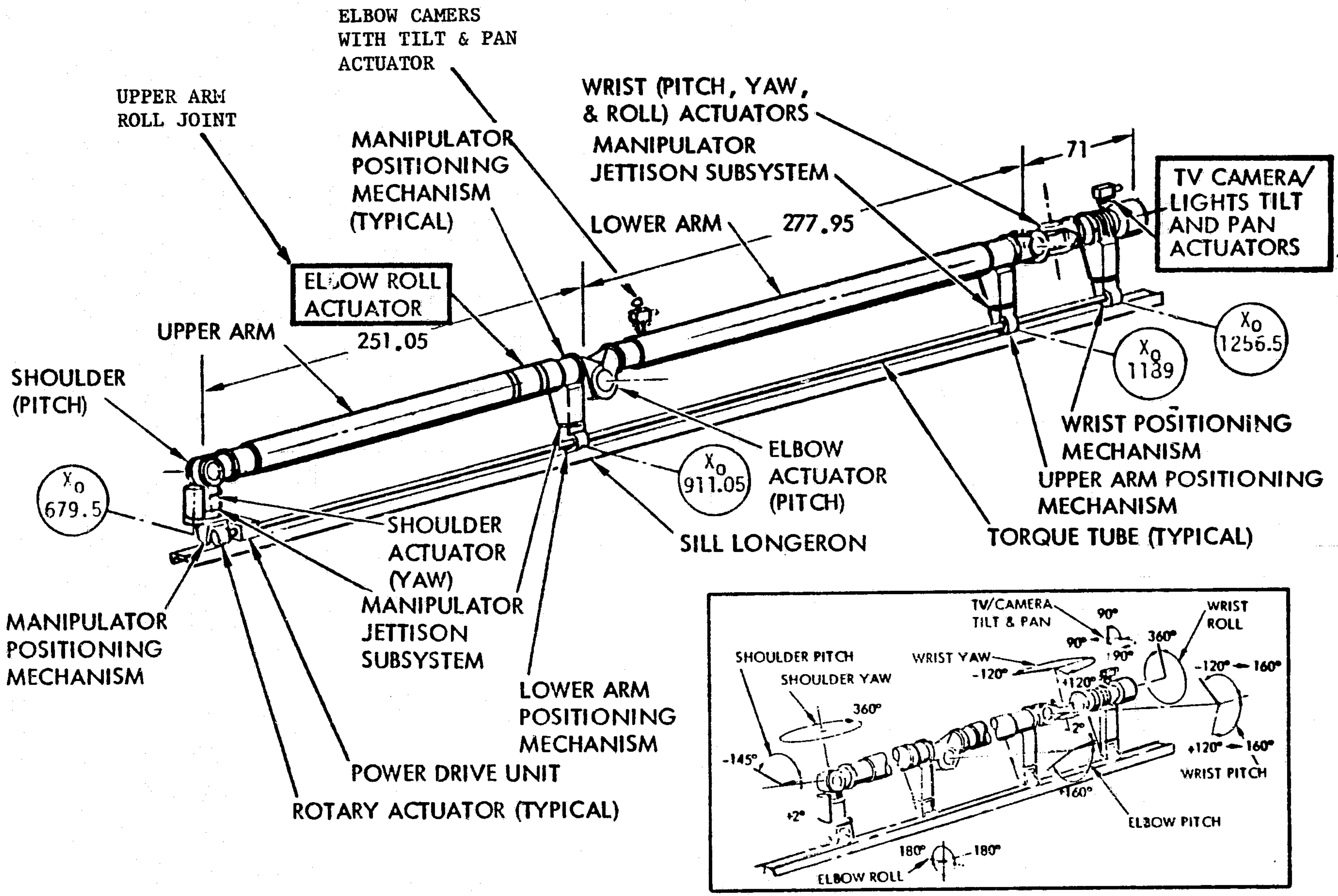
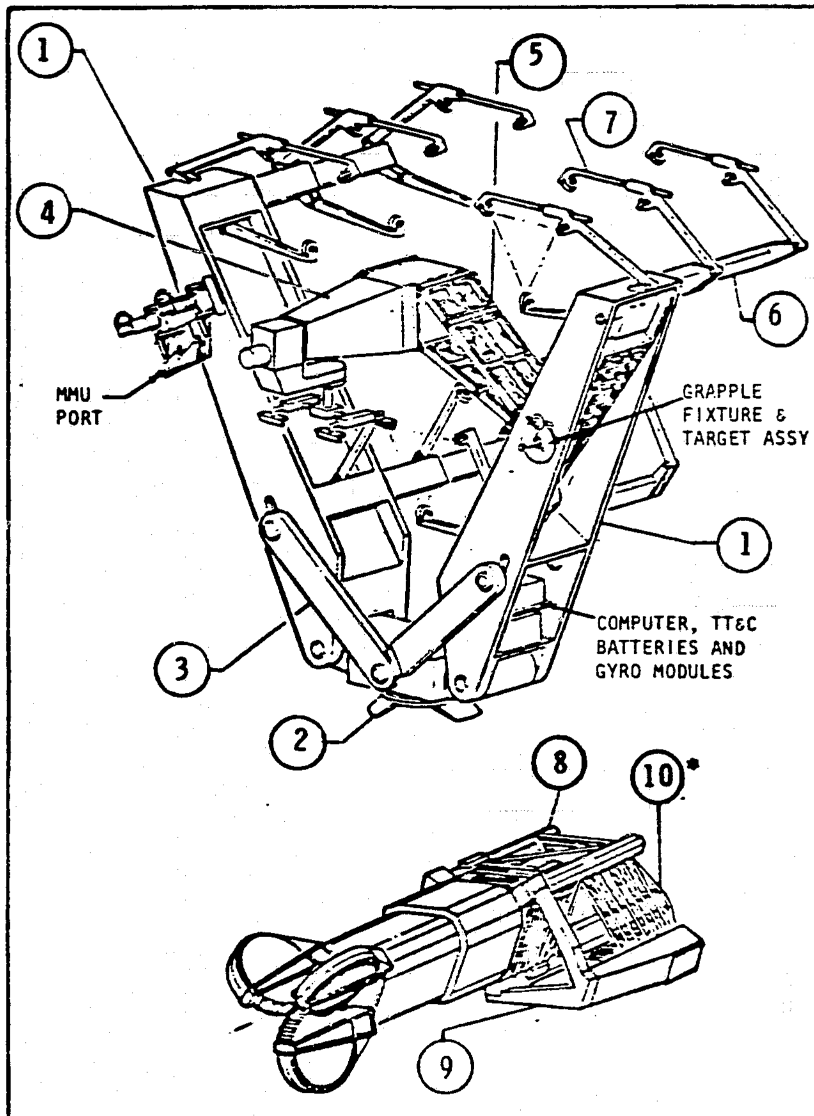


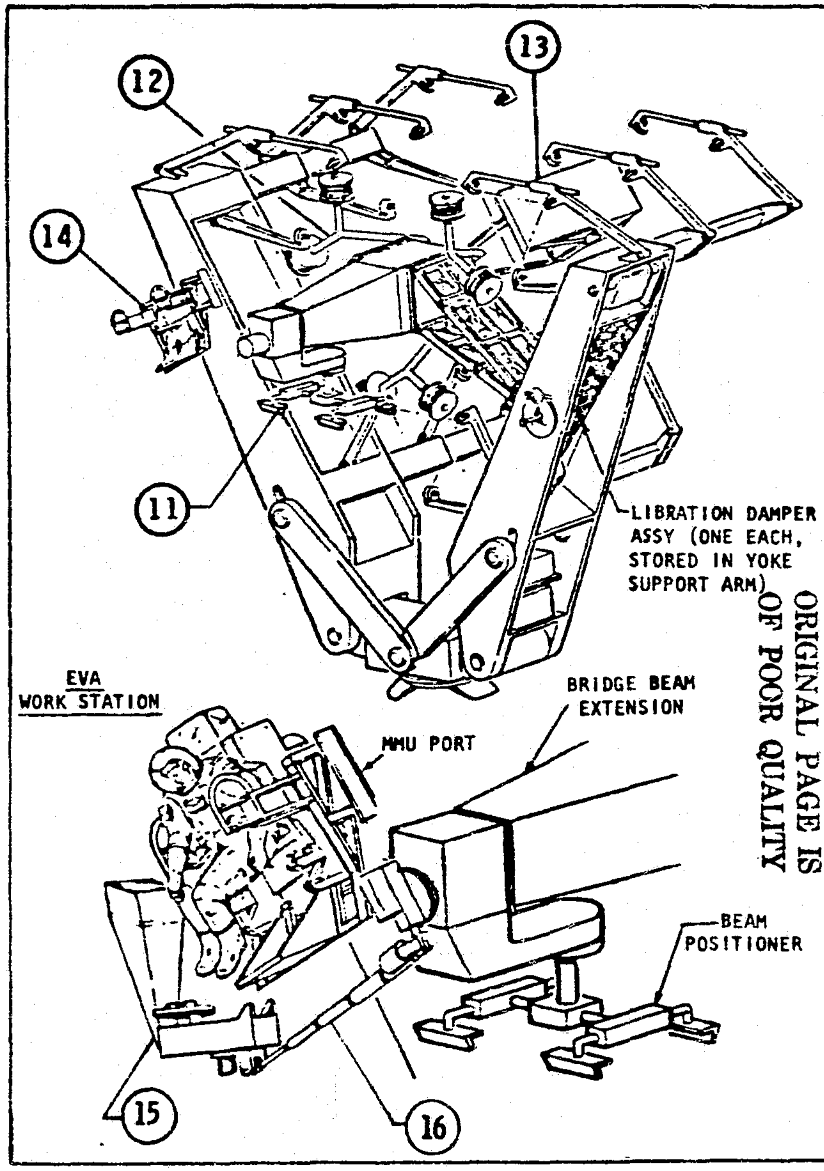
Figure 5.4-10. Remote Manipulator System Modifications



*(ATTACH PORT POSITIONER-WELDER) OPPOSITE VIEW NOT VISIBLE IN THIS VIEW; SEE FIGURE 5.4-12.

I.D.	DESCRIPTION
1	BUILDING FIXTURE SUPPORT YOKE. THE TWO ARMS OF THIS STRUCTURE FORM THE BASIC SUPPORT ELEMENTS OF THE BUILDING FIXTURE. THE ARMS ALSO PROVIDE THE SUPPORT FOR ALL THE MECHANICAL FUNCTIONS REQUIRED TO FABRICATE THE LONGITUDINAL BEAMS FOR THE ENGINEERING TECHNOLOGY VERIFICATION PLATFORM.
2	BUILDING FIXTURE BRIDGE & BERTHING PORT. THIS BRIDGE JOINS & SUPPORTS THE ARMS OF THE BUILDING FIXTURE & ALSO CONTAINS HALF OF A 4-PETAL BERTHING ADAPTER SYSTEM. CONTAINED WITHIN THIS PART ARE ALL THE REQUIRED ELECTRICAL INTERFACE CONNECTIONS TO PROVIDE BOTH POWER & DATA READOUT BETWEEN THE ORBITER AND THE ENGINEERING TECHNOLOGY VERIFICATION PLATFORM (ETVP).
3	BUILDING FIXTURE RIGIDIZING LINKS. THE 2 LINKS SHOWN PROVIDE CONTROL OF THE FIXTURE SUPPORT ARMS DURING DEPLOYMENT BY UTILIZING THE BUILT-IN POWER DRIVE SYSTEM. ALSO, THEY PROVIDE RIGIDIZING OF THE FIXTURE WHEN THE CORRECT ARM POSITION IS ATTAINED.
4 & 5	BRIDGE BEAM EXTENSION & BRIDGE BEAM FOLDING SUPPORT STRUCTURE. THE BRIDGE BEAM EXTENSION IS A STRUCTURAL ENCLOSURE THAT SUPPORTS THE BEAM BUILDER, THE CROSS-CORD STORAGE REEL CLUSTER, AND THE DATA/POWER CABLE STORAGE REEL. WITHIN THE BODY OF THIS STRUCTURE ARE HOUSED ALL THE POWER AND DRIVE ACTUATORS THAT OPERATE THE COMPONENTS ATTACHED TO THIS HOUSING. THIS STRUCTURAL ASSY IS IN TURN SUPPORTED BY 4 HINGED & FOLDING SUPPORT ARMS WHICH ARE ATTACHED TO THE BUILDING FIXTURE BY AN ELECTROMECHANICAL LATCH SYSTEM WHICH CAN BE RELEASED BY REMOTE CONTROL FROM THE CREW CABIN. WHEN THE LATCHES ARE RELEASED THE 4 ARMS AUTOMATICALLY FOLD & ROTATE SO THAT THE WHOLE STRUCTURE CAN BE REMOVED FROM THE BUILDING FIXTURE AND STORED IN THE ORBITER.
6 & 7	EXTENDABLE SUPPORT BOOMS & ROLLER SUPPORT ARMS. THIS EXTENDABLE BOOM PROVIDES SUPPORT FOR THE LONGITUDINAL BEAM SUPPORT ARMS. AN ACTUATION DEVICE LOCATED AT THE BASE OF THE SYSTEM EXTENDS THE BOOM, TRANSPORTING WITH IT THE LONGITUDINAL BEAM SUPPORT ARMS. POWER IS PROVIDED TO THE ROLLER ARMS BY INTERNAL LEADS ORIGINATING AT THE ORBITER/FIXTURE INTERFACE. THE FUNCTION OF THESE ARMS (3 SETS OF 6 ARMS EA, & 1 SET OF 3 ARMS) IS TO PROVIDE BEAM SUPPORT DURING FABRICATION AND ALSO DURING PLATFORM TRANSLATION THROUGH THE BUILDING FIXTURE.
8	BEAM BUILDER. THIS MACHINE IS UTILIZED TO AUTOMATICALLY FABRICATE SPACE STRUCTURAL ELEMENTS FROM COMPOSITE MATERIALS. THE STRUCTURE CONSISTS OF 3 MAJOR SEGMENTS—A FORMING SECTION, A CENTRAL SUPPORT SPIDER, & A FINAL BEAM SUPPORT SECTION. ADDITIONAL SUBSYSTEMS WITHIN THE MACHINE ARE MATERIAL REELS, CORD PLYERS, WE[illegible], AND A BEAM CUTOFF SYSTEM.
9 & 10	THE BEAM BUILDER SUPPORT TRIPOD [illegible] ATTACH PORT MAGAZINE AND ATTACH PORT POSITIONER & WELDER. THE BEAM BUILDER SUPPORT TRIPOD IS A SPECIAL TOOL WHICH PROVIDES THE INTERFACE BRIDGE BETWEEN THE BRIDGE BEAM EXTENSION (ITEM 4) & THE BEAM BUILDER. IN CONJUNCTION WITH THIS TRIPOD IS A MAGAZINE CONSISTING OF 6 BEAM END ATTACH PORTS. ALSO ON THE BEAM BUILDER IS A PORT POSITIONER WHICH CORRECTLY POSITIONS THE PORTS ONTO THE LONGITUDINAL BEAM ENDS. THIS OPERATION IS THEN FOLLOWED BY THE APPLICATION OF ELECTRIC CURRENT THROUGH THE PORT POSITIONER HEAD ASSEMBLY TO WELD THE PORTS TO THE BEAMS BY ELECTRIC RESISTANCE HEATING OF A BONDING MATERIAL.

Figure 5.4-11. Construction Station No. 1 & Beam Builder Machine



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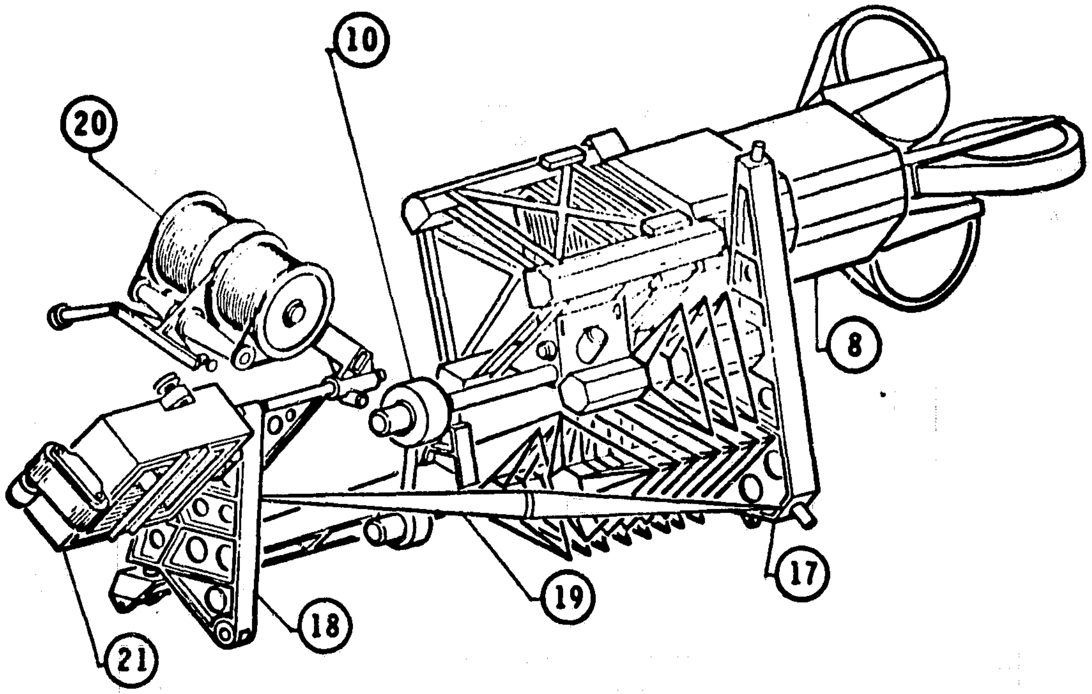
I.D.	DESCRIPTION
11	BEAM POSITIONER. THIS UNIT PROVIDES THE CONTROL THAT IS NECESSARY TO POSITION AND HOLD EITHER THE LONG OR SHORT CROSSBEAMS AND THE TRANSVERSE BEAMS DURING THAT ASSEMBLY PERIOD WHEN THE BEAMS ARE BEING ATTACHED TO THE PLATFORM LONGITUDINAL BEAMS. THIS UNIT HAS BUILT-IN CAPABILITY OF MOVEMENT IN THREE AXES. THE PLANE OF THE BEAM GRIP CLAMPS CAN BE RAISED OR LOWERED. THE GRIP CLAMPS, IN TURN, CAN BE EXTENDED OR RETRACTED OR MOVED LATERALLY TO ENSURE THAT THE POSITIONER CAN PICK UP THE BEAMS FOR ATTACHMENT. FOLLOWING THE JOINING OF THE CROSSBEAMS OR TRANSVERSE BEAMS TO THE LONGITUDINAL BEAMS, THE POSITIONER IS CONTROLLED TO EXERT A PRE-DETERMINED TENSILE LOAD ON THE JOINT TO VERIFY STRENGTH OF THE ASSEMBLY.
12	DIAGONAL CROSSBRACE CORD STORAGE REELS. THE 6 REELS INVOLVED IN THIS ASSEMBLY SEQUENCE PROVIDE THE SUPPLY SOURCE FOR ALL THE DIAGONAL CROSS-BRACE CORDS ON THE PLATFORM STRUCTURE. WHEN DEPLOYED INTO THEIR DISPENSING POSITION, AN ASTRONAUT IN THE CORRECT LOCATION WILL HOOK THE CORD ENDS TO ATTACH POINTS ON THE INTERSECTION FITTINGS AT THE BEAM INTERFACES. AS THE PLATFORM ADVANCES THROUGH THE BUILDING FIXTURE THE CORDS WILL BE PULLED FROM THE REELS. WHEN THE NEXT CROSS FRAME IS REACHED, THE ASTRONAUT WILL ATTACH THE CORD ENDS TO THE INTERSECTION FITTING AT THIS STATION. THIS PROCEDURE CONTINUES UNTIL CROSSBRACE CORDS HAVE BEEN INSTALLED IN ALL PLANES BETWEEN CROSSBEAMS OF THE COMPLETE PLATFORM.
13	DATA/POWER CABLE STORAGE REEL. THIS STORAGE REEL CONTAINS ALL THE CABLES, CONNECTORS, AND VELCRO ATTACH STRIPS REQUIRED TO PROVIDE THE COMPLETE CABLE RUNS AND BREAKOUT LEADS TO THE CROSSBEAMS. ELECTRICAL CABLES EXTEND THE FULL LENGTH OF THE PLATFORM, ORIGINATING AT THE SYSTEM CONTROL MODULE AND TERMINATING AT THE PROPULSION MODULES. CABLE DISPENSING AND ATTACHMENT TO THE STRUCTURE ARE PERFORMED AUTOMATICALLY BY SYSTEMS BUILT INTO THE UNIT AS THE LONGITUDINAL BEAMS PASS THROUGH THE BUILDING FIXTURE.
14	MMU PORT. THE FUNCTION OF THIS EQUIPMENT IS TO PROVIDE A DOCKING PORT FOR THE ASTRONAUT AND HIS MMU. THE ASTRONAUT WILL MOVE TO THIS PORT WITH HIS MMU AND PROCEED TO DOCK TO THE PORT'S LATCHING MECHANISM. AFTER SECURING HIS MMU, HE WILL THEN SEPARATE FROM IT, AND TRANSFER TO THE EVA WORK STATION (ITEM 15) TO PROCEED TO HIS ASSIGNED WORK TASK.
	EVA WORK STATION—THIS WORK STATION CONSISTS OF A MODIFIED OPEN CHERRY PICKER (ITEM 15) WHICH IS ATTACHED TO AND CONTROLS THE MOTION OF A POSITIONING ARM (ITEM 16)
15	MODIFIED CHERRY PICKER. THE GRUMMAN CONCEPT FOR AN OPEN CHERRY PICKER IS MODIFIED BY REMOVING THE STABILIZER ARM, LIGHT STANCHIONS, TOOL BIN, AND PAYLOAD SUPPORTS. LIGHTS ARE RELOCATED ON THE CONTROL/DISPLAY PANEL. THE COMPACT DESIGN ALLOWS ACCESS TO CONFINED SPACES. CONTROL OF THE BEAM POSITIONER IS INCLUDED ON THE CONTROL/DISPLAY PANEL.
16	POSITIONING ARM. THIS POSITIONING ARM IS THE SUPPORT BOOM FOR THE MODIFIED CHERRY PICKER. THE POSITIONING ARM HAS THE CAPABILITY OF ROTATION ABOUT ITS SUPPORT INTERFACE, AND THE ABILITY TO TELESCOPE, SO THAT THE ASTRONAUT ON THE EVA WORK STATION CAN BE POSITIONED IN ALL AREAS REQUIRED FOR HIS ASSEMBLY WORK.

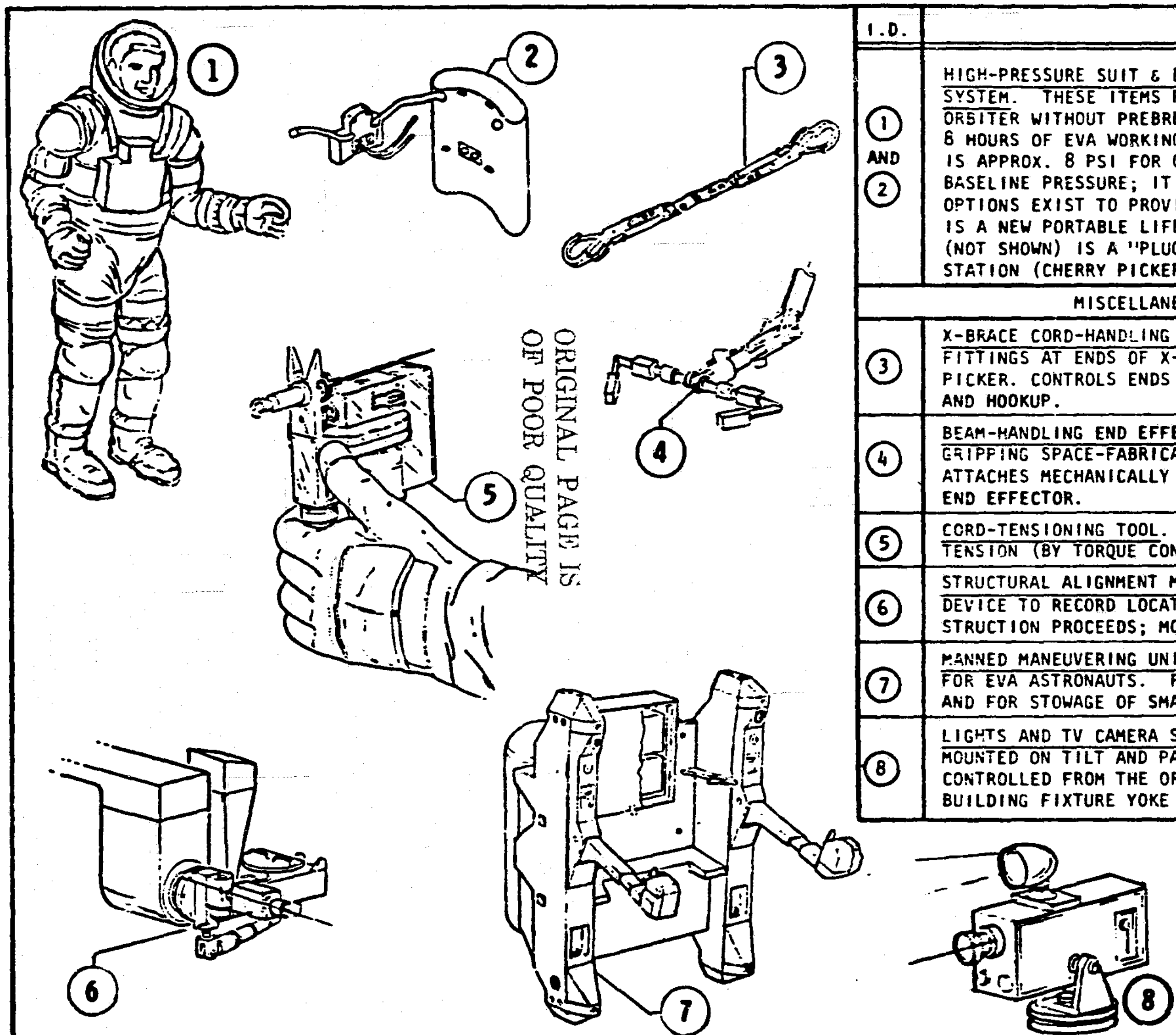
Figure 5.4-11. Construction Station No. 1 & Beam Builder Machine (Cont'd)

CONSTRUCTION STATION NO. 2



I.D.	DESCRIPTION
8 & 10	BEAM BUILDER AND (REF. ONLY) ATTACH PORT POSITIONER-WELDER. AFTER FABRICATING THE LONGITUDINAL BEAMS IN CONSTRUCTION STATION NO. 1, THE (PREVIOUSLY DESCRIBED) BEAM BUILDER, TOGETHER WITH THE ATTACH PORT POSITIONER & WELDER DEVICE, IS RELOCATED TO THE POSITION SHOWN HERE FOR FABRICATING CROSSMEMBERS OF THE PLATFORM. (THE SUPPORT TRIPOD USED IN CONSTRUCTION STATION NO. 1 IS STOWED IN THE ORBITER BAY.)
17	Y-FRAME & ATTACH PORT MAGAZINE. THE Y-FRAME DOES DOUBLE DUTY: IT SERVES AS A CRADLE IN THE ORBITER BAY FOR STOWING & SUPPORT FOR THE BEAM BUILDER AND THE ATTACH PORT MAGAZINE. WHEN INSTALLED ACROSS THE LONGERONS OF THE ORBITER BAY, IT FORMS THE BASIC STRUCTURAL SUPPORT FOR CONSTR. STATION NO. 2 & SUPPORTS ALL OF ITS ASSOCIATED BEAM FABRICATION COMPONENTS.
18	REEL FRAME ASSY. THE REEL FRAME IS ATTACHED TO THE Y-FRAME & TO THE ORBITER LONGERON, AND IN TURN IS BRACED BY PART (21). THE ELECTRIC CABLE-LAYING MACHINE AND THE POSITIONER & WELDER FOR THE INTERSECTION FITTINGS & THE TELEOPERATOR PORTS ARE MOUNTED TO THIS FRAME. DURING STOWAGE THE ELECTRIC CABLE-LAYING MACHINE IS FOLDED ONTO THE REEL FRAME ASSEMBLY AND SECURED.
19	THE BRACING STRUT IS INSTALLED TO BRACE THE REEL FRAME AGAINST THE Y-FRAME WHEN FABRICATION & BEAM ASSEMBLY IS IN OPERATING AT WORK STATION NO. 2.
20	ELECTRIC CABLE REEL & CABLE ATTACH MECHANISM. THIS DEVICE INSTALLS ALL THE CABLES REQ'D ON BOTH THE LONG AND SHORT CROSSBEAMS. DURING OPERATION THE CABLES ARE DISPENSED FROM THE REELS & ARE ATTACHED BY ACTUATORS TO THE CROSSMEMBERS OF THE BEAM AS THE CABLES PASS ACROSS. THIS MECHANISM ALSO ATTACHES THE CONNECTORS AT EACH END OF THE CABLES TO THE CABLE/CONNECTOR HARNESS OF THE END ATTACH PORTS.
21	INTERSECTION FITTING & TELEOPERATOR DOCKING PORT POSITIONER & WELDER. THIS MAGAZINE CONTAINS ALL OF THE INTERSECTION FITTINGS (I/F) & TELEOPERATOR DOCKING PORTS (TDP) REQUIRED FOR THE FABRICATION OF ALL THE SHORT & LONG CROSSBEAMS. THE I/F's & TDP's ARE STORED IN THE SEQUENCE IN WHICH THEY ARE TO BE USED. THE POSITIONER MECHANISM EXTRACTS THE FITTING OR PORT AS REQUIRED FROM THE MAGAZINE & PLACES IT AGAINST THE CROSSBEAM IN ITS CORRECT LOCATION. THE WELDING MECHANISM, WHICH IS ASSOCIATED WITH THIS OPERATION, APPLIES BOTH PRESSURE AND ELECTRICAL CURRENT TO THE CONTACT POINTS TO COMPLETE THE ATTACH OPERATION.

Figure 5.4-12. Construction Station No. 2



I.D.	DESCRIPTION
1 AND 2	HIGH-PRESSURE SUIT & EXTENDED PORTABLE LIFE SUPPORT SYSTEM. THESE ITEMS PROVIDE CAPABILITY FOR EVA FROM THE ORBITER WITHOUT PREBREATHING OF 100% OXYGEN AND PERMIT 8 HOURS OF EVA WORKING TIME. THE SUIT OPERATING PRESSURE IS APPROX. 8 PSI FOR ORBITERS OPERATING AT THE 14.7-PSI BASELINE PRESSURE; IT MAY BE A 2-GAS SUIT. SEVERAL OPTIONS EXIST TO PROVIDE FOR 8 HOURS EVA CAPABILITY; ONE IS A NEW PORTABLE LIFE SUPPORT BACKPACK. AN ALTERNATIVE (NOT SHOWN) IS A "PLUG-IN" SUPPLY SYSTEM AT THE EVA WORK STATION (CHERRY PICKER)
	MISCELLANEOUS TOOLS AND DEVICES
3	X-BRACE CORD-HANDLING TETHER. TETHER WITH HOOKS TO GRIP FITTINGS AT ENDS OF X-BRACE CORDS AND ATTACH TO CHERRY PICKER. CONTROLS ENDS OF X-BRACE CORDS DURING CROSSOVER AND HOOKUP.
4	BEAM-HANDLING END EFFECTOR. SPECIAL END EFFECTOR FOR GRIPPING SPACE-FABRICATED BEAMS WITH CONTROLLED FORCE. ATTACHES MECHANICALLY AND ELECTRICALLY TO RMS STANDARD END EFFECTOR.
5	CORD-TENSIONING TOOL. MANUAL POWER TOOL TO APPLY PRESET TENSION (BY TORQUE CONTROL) TO X-BRACE CORDS
6	STRUCTURAL ALIGNMENT MEASURING DEVICE. ELECTRO-OPTICAL DEVICE TO RECORD LOCATION OF THE FRAME JOINTS AS CONSTRUCTION PROCEEDS; MOUNTS ON BUILDING FIXTURE.
7	MANNED MANEUVERING UNIT (MMU). PERSONAL TRANSPORT DEVICE FOR EVA ASTRONAUTS. FACILITATES ACCESS FOR INSPECTION AND FOR STOWAGE OF SMALLER CARGO ITEMS.
8	LIGHTS AND TV CAMERA SYSTEMS. LIGHTS AND TV CAMERAS MOUNTED ON TILT AND PAN MECHANISMS WHICH ARE REMOTELY CONTROLLED FROM THE ORBITER CABIN. LOCATED ON THE BUILDING FIXTURE YOKE AND BEAM BUILDER.

Figure 5.4-13. Additional Construction Support Equipment

items are strongly involved in the new technology requirements for space construction. Some important considerations of major CSE items related to the first mission are highlighted in the following discussion.

(a) Remote Manipulator System (RMS) Modifications

Figure 5.4-10 illustrates potential changes to the RMS. The standard orbiter RMS must be modified to perform the construction as defined in this study. An upper-arm roll joint, or its equivalent capability, and associated software are required to provide the upward reach needed to install crossbeams, transverse beams, RCS modules, and payloads. This is primarily required by the location of the height of the apex beam of the ETVP above the RMS shoulder joint, but is also driven by the overall close-in location and limited clearances of the construction fixture work stations. This new mobility capability is considered by Rockwell to be of fundamental importance for space construction and highly useful for transfer of payloads to potential on-orbit stations. The design penalties and procedures to "get around" the lack of this capability seem to be unwarranted and usually complex. For example, there could be a telescoping joint or a scissors mechanism between the construction fixture yoke and the orbiter, near the docking port. Such a joint would have to be extended frequently to clear the elbow motion when the RMS is to reach upward. However, the extra weight and complexity of electrical umbilicals introduced would render this type of solution highly undesirable. Furthermore, the current arm has only 145-degree shoulder rotation, thus limiting the possible range of upper-arm motion angles to no less than 35 degrees above the plane of the payload bay door hinges when the RMS is reaching upward. With the upper-arm rotary joint concept, the upper arm could be oriented in a plane parallel with the payload bay door hinges when reaching upward. As a practical operational consideration, the upper-arm rotary joint greatly simplifies the number of motions and time to accomplish removal of items from the payload bay and their subsequent transport and installation to structure above the payload bay (such as the primary construction fixture). This advantage has been identified in other Rockwell studies, such as those relating to the 25-kW power module or service module, as well as various erectable structures.

Another highly desirable modification to the RMS hardware is tilt and pan capability for the wrist camera and lights. Although this feature is not specifically identified as a requirement for the construction process, there are several operations which it could facilitate. Among these are the setting up of the construction stations, moving the beam builder machine, and transporting beams.

Certain software changes are essential for implementing the upper-arm rotation joint concept. A current concept for the use of this joint is that it would be limited to a single-joint rotation mode. Other joints would be braked when the upper-arm joint is rotated and vice versa. This could simplify the software changes and prevent confusions resulting from multiple solutions to specific resolved motion calculations. Other RMS software improvements are also desirable to aid construction. In particular, collision avoidance warning signals and/or disabling signals would greatly increase operational safety for handling large modules, struts, and beams in the vicinity of the construction stations. Special end effectors for use with the RMS are considered in later discussions.

(b) *Construction Station No. 1*

The concept for this key construction station (which has also been referred to as the *construction fixture*) sets the major activity patterns and enables on-orbit construction out of the orbiter as described in this study. As indicated in Figure 5.4-11, the station includes a basic building fixture having a yoke shape to accommodate the tri-beam configuration of the ETVP cross-section, and roller supports which grip the longitudinal beams after they are fabricated and cut off from the beam builder machine. Centrally located in the yoke is a removable cross-bridge structure incorporating a rotating head which accepts several types of auxiliary devices, including an EVA work station as well as the beam builder machine, during fabrication of the longitudinal beams. Considering the multiplicity of fabrication and assembly functions performed at this station, it may be thought of as a small satellite space factory. It is designed for cost effectiveness and power conservation, using the concept of a compact, efficient work space through which the structure is moved in either of two directions (and later rotated) to accomplish the construction.

This concept permits a minimum of power for illumination and TV services, maximizes use of a single Shuttle RMS for handling and installation of components, minimizes EVA travel time and fuel/power demand, and provides for extraordinary flexibility in scheduling installations and in LEO servicing of individual payload modules and spacecraft modules (e.g., RCS pods and control modules). It is designed to be stowed in the orbiter bay in a relatively compact manner, permitting initial removal and setup on a docking port as if it were a standard orbiter payload package. The major portion of the station is designed for semi-automatic, remotely controlled deployment which takes place within a relatively short time. Selective reconfigurations are required during the first mission. The major item of removable equipment is the central cross-structure/rotary joint complex to which are attached a beam positioner, wire-laying reel, and astronaut maneuvering arm/cherry picker during the ascent phase. During the initial setup, the beam builder on its tripod support (and carrying the attachment port installation device) is also attached. This central complex of machinery must be removed after attaching the transverse beams and crossbeams in order to permit freedom of translation of the yoke along the longitudinal axis of the platform for later installation work. Such removal activity is accomplished during the stowage of items prior to separation and return of the orbiter to the ground. Additional capabilities needed for the station to accomplish construction are discussed later in conjunction with the second and third missions.

During unattended operations (between construction periods), this station also provides libration damping and TT&C. It has solar arrays and batteries for power during this period. Thus, it functions as a part of an active satellite, controllable from the ground.

(c) Beam Builder Machine Modifications

An essential element of space fabrication technology is the automatic beam builder machine, which is defined for this study as a derivation of the General Dynamics SCAFE design (References 5-3 and 5-4). The construction concept developed herein requires serial use of the beam builder in the two construction stations, and requires selective modifications of the baseline software to provide for double cross-members (side by side) at selected points along the longitudinal beam which carries the electrical wiring. These special situations occur adjacent to the long crossbeams in order to provide stiffness and strength for supporting breakouts and connectors for the electrical wiring which is routed to the crossbeams. Software revisions are also required to provide for special end configurations on transverse beams and crossbeams. The transverse beams configurations require that one cross-member be deleted (together with adjacent cross-brace cords) at each end. Also, a shorter spacing between cross-members is needed at the end bays, in order to avoid interference with adjacent beams at the ends. This change permits the crossbeams and transverse beams to be located in the same plane at each frame station of the platform, and simplifies construction procedures over an offset plane configuration. These software modifications have been reviewed by General Dynamics and verbal agreement received regarding their feasibility.

Other basic modifications include use of thicker cap materials and larger diameter cross-brace cords. These thicker materials will require somewhat more power for heating and welding (the power estimates used in this study have been set higher to account for these differences). Another requirement for materials stored in the beam builder machine is the provision of Velcro strips on selected cross-members to support electrical wiring. Preliminary investigation has indicated space availability exists for these provisions.

In order to provide structural mounting points and pickup points for transport, some modifications to the beam builder machine framework will also be required. In a similar category are installation points for a device which installs attachment ports on the ends of the fabricated longitudinal beams and crossbeams, and targets for guiding the RMS to a favorable grapple position.

Finally, provisions are required for electrical wiring, connectors, and mechanical attachments for remote control of the beam builder, for the attachment port installation devices, for lights, and for a TV camera and its associated tilt and pan mechanisms and heaters. The TV camera, heaters, and mechanism systems are currently assumed to be identical or highly similar to those specified for the RMS elbow. It is assumed that the camera and lights can aid in observation of beam fabrication, attachment port installation, and beam handling (grappling and initial transport phases) at Construction Station No. 2 (which is discussed later).

In the construction analysis and fixture design concepts adapted for this study, the beam builder machine would be part of an assembly which includes the attachment port installation device, lights, and TV camera. Initially, it would also have attached to it a support tripod which mates with the rotating head on the central portion of the primary construction fixture. This mating interface would have both mechanical attachments and electrical power and signal connections. It would be designed to facilitate interface alignment when using the

RMS as a transporting device. Design features would include latches which are normally remotely controlled from the orbiter and manually operated in contingency modes (by EVA). Also needed are alignment guides and targets. Ideally, the joining interface would be visible using both the RMS and a separate TV camera mounted on the construction fixture.

(d) EVA Work Station (Modified Cherry Picker and Astronaut Maneuvering Arm)

Two major items constitute the unit called the EVA Work Station for the first mission, as shown in Figure 5.4-11. They are discussed here as separate entities because it is planned to use the modified cherry picker during the second mission in conjunction with the RMS.

The modifications are applicable to the Grumman concept of an open cherry picker platform (Reference 5-5). The first-mission requirements include removal of a stabilizer arm, a tool bin, and two light stanchions. Also, relocation of miscellaneous features is planned to minimize workspace volume requirements. It is currently assumed that there will be three 60-watt lamps on this unit and a minimal tool storage capability. The cherry picker control/display panel is used to control the astronaut maneuvering arm and to control the beam positioner.

The astronaut maneuvering arm concept is an entirely new piece of machinery, although it performs many of the same functions as the RMS. It would be much smaller in extended length and would incorporate a telescoping arm link to facilitate maneuvering within the confined space of the tri-beam platform. The mass handling capability is also severely scaled down from that of the RMS, since only the EVA crewman and modified open cherry picker are to be transported. Consequently, the power demands for driving this device are assumed to be much less than for the RMS. Also, it is presumed to require minimal (or none) heating of its drive mechanisms by virtue of its relatively short useful life and lowered requirements for accuracy in positioning.

At the end of the first mission, the cherry picker is to be returned to earth for rework. These changes, required to support the second mission, will include a stabilizer arm and tool holder as well as added light stanchions. Thus, the configuration will more nearly resemble Grumman's baseline concept for the development test article/open cherry picker (Reference 5). Earlier in the systems analysis it was planned to leave the modified open cherry picker in space, secured to the construction fixture. However, subsequent analysis of the second-mission requirements indicated the need for the added features noted above. These changes were of such significance that shop assembly was considered more desirable than field rework.

(e) Construction Station No. 2

This station consists of a number of important separate equipment items of special-purpose nature which assist in automatic fabrication of assemblies of crossbeams and transverse beams. As shown in Figure 5.4-12, the station includes a beam builder support and control, the dispensers for attachment ports, the devices for installing intersection fittings and remote servicing (teleoperator) docking ports, reels, and installation devices for electrical

lines, and supporting/translating rollers for beam translation when beyond the beam builder machine. Use of such devices facilitates rapid construction and high productivity of the crew. The location assists in achieving simultaneous production of beams and installation of beams, hookup of cross-brace cords, and electrical connections on the platform.

Design of this secondary station includes use of a structure (Y-frame) which acts both as a support cradle during launch and return and a construction fixture for on-orbit operations. There is also a separate, more specialized reel assembly fixture to which is also attached the dispenser for intersection fittings and teleoperator docking ports. These components are all returned to earth at the end of the first mission.

(f) EVA Suit and Life Support Systems

Baseline crew schedules for the first mission are tied to the use of a new high pressure suit (5 to 8 psi) and an eight-hour EVA life support system. Until such a suit system is designated as an inherent and integral part of the Shuttle development program, it may be considered as special-purpose construction support equipment. In fact, an extended work time capability (8 hours in lieu of 6 hours) could be separately provided by an auxiliary supply of breathing gas, fluids, and electrical power through umbilicals which could be incorporated into the cherry picker/maneuvering arm system, with minimal impact on portable life support system (backpack) development. However, a trade study to select between these approaches or other feasible means to extend work time is considered outside the scope of this study.

(g) Miscellaneous Tools and Devices

Included in this group of CSE are the special end effector for handling crossbeams and transverse beams with the RMS, and the hand tool for tensioning cross-brace cords. Also included is the tether used to assist handling of cross-brace cords hookup and crossover (Activity 11.2).

A set of EVA hand tools will also be required for contingency usage in the construction operations. Although unspecified at the preliminary analysis of this study, experience gives certainty that they will be needed. Illumination devices and TV cameras are also significant aids to productivity in manned construction activities. Although they have no direct physical impact on actual assembly of parts, they must be carefully located and selected due to their potential impact on power demands. Lighting and TV requirements for the first mission are discussed in greater detail in Section 5.4.3.

The electro-optical system for performing structural alignment checks of the platform is another item of rather indirect relationship to the construction operations. It is located on the central portion of the construction fixture as described in Appendix B (Construction Activity Data Sheet 16.0). Its function is in the nature of inspection and reporting rather than fabrication or assembly. Yet, like diameter gauges and micrometers for machining operations, it is a piece of construction support equipment.

(h) Manned Maneuvering Unit (MMU)

As currently planned, all the construction of the ETVP could be performed without the aid of an MMU. However, the MMU is included here as a construction support device which facilitates EVA crew transport for inspection and miscellaneous manual functions at the beginning and the end of the EVA work period in the first mission. As a facilitator, it saves crew transport time by deleting hand-over-hand translation by the crew along rails and handholds. The most valuable contribution of the MMU could lie in its usage for dealing with unforeseen contingencies. Examples might be manual deployment or retraction of elements with motor or solenoid failures, release of latches which hang up, assisting with alignment of parts for assembly or stowage, making repairs to loosened fasteners, or replacement of failed parts. Initial usage could be merely visual assessment of a problem to gain information for decisions on how to deal with it.

Another subsidiary, but important, usage could be photographic coverage of key construction operations. If necessary, EVA transport of structural elements could be performed in the unlikely case of failure of an RMS drive motor or other transport device.

As a means to facilitate rapid response by the EVA crew, the design of the construction fixture incorporates a fixture for holding an MMU in close proximity to the EVA work station. This holding fixture is similar to the flight support station for the MMU in the orbiter payload bay, but it has no recharge facilities.

(i) Summary of Usage

Table 5.4-4 summarizes the usage of construction support equipment in the first mission as a function of the activities performed. The chart shows that many pieces of equipment are used in different activities, demonstrating a high level of versitility. Other items have highly spacialized functions, which raise questions of cost effectiveness, such as might be explored in detail trade studies in a Phase B type study.

It will be shown in analyses of later missions that the construction fixture, RMS and cherry picker are highly useful and effective equipment for additional functions.

5.4.6 <u>Flight and Site Support Equipment Required</u>

In addition to support equipment which is dedicated specifically to construction on the first mission, there is a need for pallets and various other flight support equipment items on components which are required to fly construction equipment and supplies to orbit and to unload/reload cargo. Also, kits containing fuel gases and various supplies for crew support may be included. The scope of this study does not include detail development of configurations or specifications for all such equipment. However, weight and volume concerns associated with end-to-end mission analysis require at least preliminary consideration of this type of equipment, particularly as regards

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Rockwell International

Table 5.4-4. Construction Support Equipment Usage - First Mission

CONSTRUCTION ACTIVITY ↓ / CONSTRUCTION SUPPORT EQUIPMENT →	RMS (Modified)	Upper Arm Roll Joint	Tilt/Pan-TV/Light	Standard End Effector	Construction Station No. 1 (with Docking Port)	Bridge Beam Extension and Support Structure	Support Booms/Roller Arms	Electrical Wire Reel/Installer	Beam Builder Rotating Support	Beam Positioner	EVA Work Station	MMU Docking Device	X-Brace Cord Reel	Beam Builder Machine	Attachment Port Installer	Attachment Port Magazine	Tripod	Construction Station No. 2	Beam Builder Support	Attachment Port Magazine	Electrical Wire Reel/Installer	Intersect. Fitting Installer/Docking Port Instal.	Rollers	EVA Suit (8 psi)	8-hr LSS	Miscellaneous Tools and Development	Beam Handling End Effector	Tensioning Tools	Tether—Cords	Struct. Alignment Optical Development	Lights Constr. Systems — RMS Wrist	Constr. Systems — Construction Fixture	Constr. Systems — Beam Builder	Orbiter — Forward Bulkhead	Orbiter — Forward Bay	Orbiter — Mid Bay	Orbiter — Aft Bay	Cherry Picker (EVA Work Station)	TV — RMS Wrist	— RMS Elbow	— Construction Fixture	Aft/Down	Forward	Beam Builder/Attach Port Installer	MMU
1.0 Erect and deploy construction fixture	X		X	X																											X			X					X						
2.0 Install beam builder on construction fixture	X		X	X	X	X			X								X																X				X								
Check out beam builder					X									X			Y																											X	
3.1 Fabricate longitudinal beam					X		X		X					X			Y																												
3.2 Install attach ports on longitudinal beam					X										X	X	X														X		X											X	
7.0 Set up Construction Station No. 2	X		X	X														X	X	X	X	X															X					X			
4.0 Reposition beam builder 120 degrees					X	X								X	X	X	X														X		X												
5.1 Withdraw longitudinal beam No. 1					X		X																									X									X				
5.2 Install electric lines on longitudinal beam No. 1					X			X																																	X				
6.0 Return longitudinal beam No. 1 to fabrication position					X		X																									X									X				
8.1 Relocate beam builder to Construction Station No. 2	X	X	X	X	X				X					X	X	X	X		X	X												X	X				X								
Check out beam builder at Construction Station No. 2														X	X	X																	X									X		X	
RMS end effector change	X			X																						X						X				X	X		X		X				
EVA astronaut egress and inspection tour																								X	X							X			X	X	X								X
9.1 Fabricate transverse beam																																													
9.2 Join intersection fittings to transverse beam																		X				X	X																						
10.0 Transport transverse beam	X	X	X	Y	X					X	X															X					X	X	X				X		X	X	X	X	X		
8.2 Reconfigure construction fixture & occupy EVA station					X	X				X	X	X	X											X	X							X						X					X		X
11.1 Join transverse beam to longitudinal beams					X	X				X	X																					X						X							
11.2A Initial connection of X-brace cords					X	X					X		X																									X							
11.2B Join X-brace cords to leading and trailing ears					X	X					X		X															X										X							
11.3 Tension X-brace cords					X	X					X																X											X							
12.1 Transport transverse beam	X	X	X	Y	X	X				X																X						X	X					X	X	X	X	X		X	
12.2 Fabricate crossbeam (long/short)														X				X	X		X	X	X										X											X	
12.3 Install attach ports on crossbeam														X	X	X		X		X			X										X											X	
12.4 Install electric lines on crossbeam														X				X			X												X												
12.5 Install teleoperator docking ports														X				X				X											X												
13.0 Transport crossbeam	X	X	X	Y	X	X				X	X															X												X							
14.0 Connect electric lines from crossbeam to longitudinal beam											X																											X							
15.0 Translate structure one bay length							X																																						
16.0 Check structural alignment					X																									X															
17.1 Configure construction fixture for untended operations					X																																								
17.2 Stow return cargo in payload bay	X	X	X	Y																											X								X	X	X	X			

weight and volume. The cargo manifest for the first mission lists many specific items in this category under the title, *Airborne Support Equipment*. Table 5.4-5 provides a summary list of different types used for the first mission. Further discussion follows concerning unique concerns to construction missions—concerns which are generally applicable to the second and third missions.

Construction missions of the type studied in this analysis will typically require pallets which carry items which are returned to earth in a different configuration than they were launched. For example, in the first mission a portion of Construction Station No. 1 is attached to the yoke structure during ascent, but is later removed and stowed separately, for return to earth, in a different manner than it was stowed for ascent.

Table 5.4-5. Flight Support Equipment Categories for First Construction Mission

Support Cradles and Pallets
Trunnion Fittings - Fixed
Trunnion Fittings - Controlled Latch Type
Keel Fittings
Bridge Fittings - Longeron
Cryogenic Fuel Tanks and Supports
Nitrogen Tanks and Supply Systems
Wire Harness - Payload Latching Controls
Berthing Platform
MMU Flight Support Station
Displays and Controls
Seats and Restraints
Garments
Accessories - Crew
Personal Equipment - Crew
Rescue Equipment - Crew

The design of support systems which are compatible with orbiter center-of-mass limits in both ascent and descent modes is a key concern. In some cases, a pallet may have to be moved to a new position in the orbiter payload bay prior to meeting such limits for return to earth. If so, it may require a grapple fixture and target for handling by the RMS. Also, it may be desirable for a pallet to function as a construction fixture while on orbit. For the first mission, the Y-frame in Construction Station No. 2 is a specific example.

Another key concern in packaging for construction operations is the access and sequence of usage of equipment and materials. Obviously, it is desirable for those items first used to be at the top of the bay, readily reachable for usage. Alternatively, a separate, temporary stowage framework or support device may be needed. During the construction process, access considerations include not merely grappling and removal, but plans for installation or attachment to another site. Therefore, the means of attachment, including visual guidance and reach, must be carefully considered in selecting the orientation of the equipment within the payload bay.

Space-site support equipment is a relatively new category of equipment peculiar to this type of construction activity. The concept includes those items which are neither used for physical support during ascent/descent nor directly used for construction. Site support items, identified during this analysis as related to the first and second missions, are the libration damping system components, the batteries, and the TT&C equipment incorporated into Construction Station No. 1. These items provide services during unattended operations at the orbital construction site, thus maintaining the viability of the site for future rendezvous, docking, and continuation of construction.

5.5 CARGO MANIFEST

Table 5.5-1 briefly summarizes the cargo types and weights for the first construction mission. The detail, itemized list is presented in Appendix C. The listing has been broken down into three basic categories: platform items, construction items, and airborne support equipment (ASE).

Table 5.5-1. Cargo Manifest Weight Summary

		Weight (lb)	Mass (kg)
Launch Mode			
Platform items (satellite)		11,498	5,215
Construction items			
Construction fixture	5,814 lb		
Beam builder	5,738 lb		
Interconnect fitting canister	200 lb		
Support for attach ports	300 lb		
Total		12,052	5,467
Airborne support equipment		11,957	5,424
Total cargo (up)		35,507	16,106
Return Mode			
Construction fixture items		1,795	
Beam builder		5,738	
Interconnect fitting canister		200	
Support for attach ports		300	
Airborne support equipment		11,957	
Less expendables		- 1,033	
Total cargo (return)		18,917	8,581

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The following assumptions were made in the development of the cargo mass statement:

1. Mission time reduced sufficiently from orbiter basic 28 man-days, that six men for 4.67 days results in the base 28 man-days for life support consumables; thus, no consumables were added for crew life support.

2. Ten additional airlock repressurizations; a total of 12 is required (two are orbiter baseline). Each nitrogen tank kit has a capacity of 4.5 EVA's. Thus, three additional N_2 tank kits are required (Kits 5, 6 and 7). The oxygen required for repressurizing the airlock is 2.7 lb. Thus, 27 lb for 10 additional repressurizations. The additional Cryokit (see next item) provides an excess of 56 lb of oxygen that can be used for this loss.

3. Cryokit 3 has been added over the orbiter two-kit baseline. In addition to supplying electrical power, it has the benefit of supplying oxygen for airlock repressurization (see Item 2).

4. Fixed life support items are added for two additional crewmen.

5. All cryo O_2 and H_2 are consumed for return. Forty pounds per tank of N_2 gas are consumed for return.

Typical of previously analyzed space construction material shipments, the payload limits are set primarily by the volume of the orbiter payload bay, not by the orbiter's payload weight capacity. Figure 5.5-1 defines the concept of payload bay packaging for launch of the construction equipment and materials for the first mission. Included are pallets and provisions to return certain items to earth. For example, there is a special cradle included primarily for return of the central portion of Construction Station No. 1.

Figure 5.5-2 shows the cargo horizontal c.g. plotted on the orbiter c.g. envelope constraints for both the up or abort condition and for the return case. As will be noted, both cases are satisfactory from a c.g. standpoint. Also, the lateral and vertical centers of gravity are well within the orbiter c.g. envelope. The mass of the total cargo is 16,103 kg (35,507 lb). The normal return mass is 8579 kg (18,917 lb).

5.6 REFERENCES

1. Rivers, J. V. and Hollaway, T. W., Shuttle Flight Planning and Crew Activities Guide. Shuttle Working Paper JSC-07996, NASA, JSC, 16 May 1973

2. Freeman, D. L. and Scales, L. V. S. STS Work Day Handbook, Orbital Flight Test, JSC 10541, LA-B-1180-4H, NASA, JSC, June 1978

3. Convair Division of General Dynamics Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), Part III Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine).

4. Telephone conversation with L. Browning, Convair Division of General Dynamics.

5. Grumman Aerospace Corporation Manned Remote Work Station Development Article, Volume I, Book 1, Flight Article Requirements, Report NSS-MR-RP008, 1 March 1979.

6. Ellis, J. L., Shuttle EVA Description and Design Criteria JSC 10615, Crew Training and Procedures Division, Flight Operations Directorate, NASA, L. B. Johnson Space Center, May 1976

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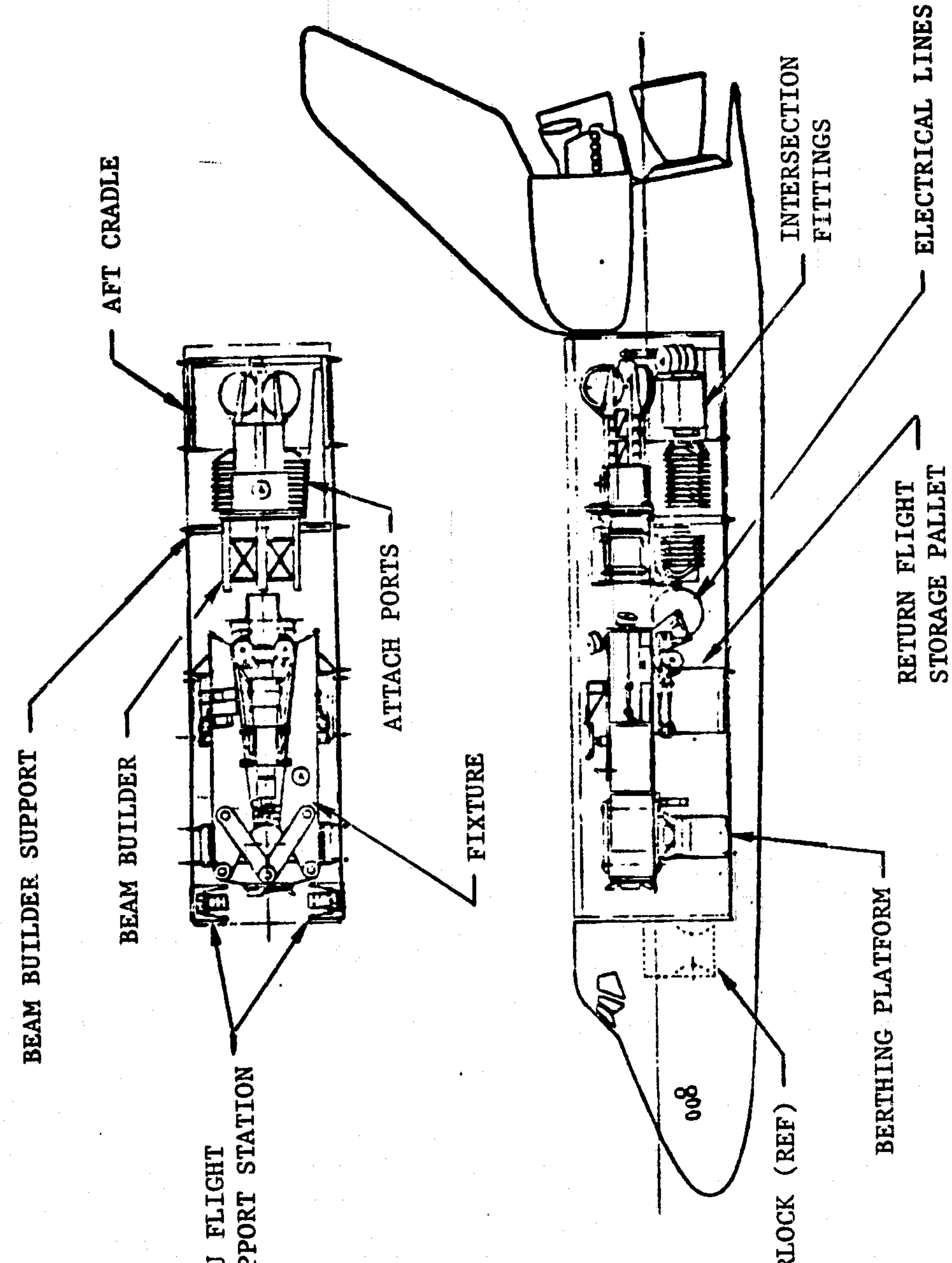

Figure 5.5-1. First Mission Manifest

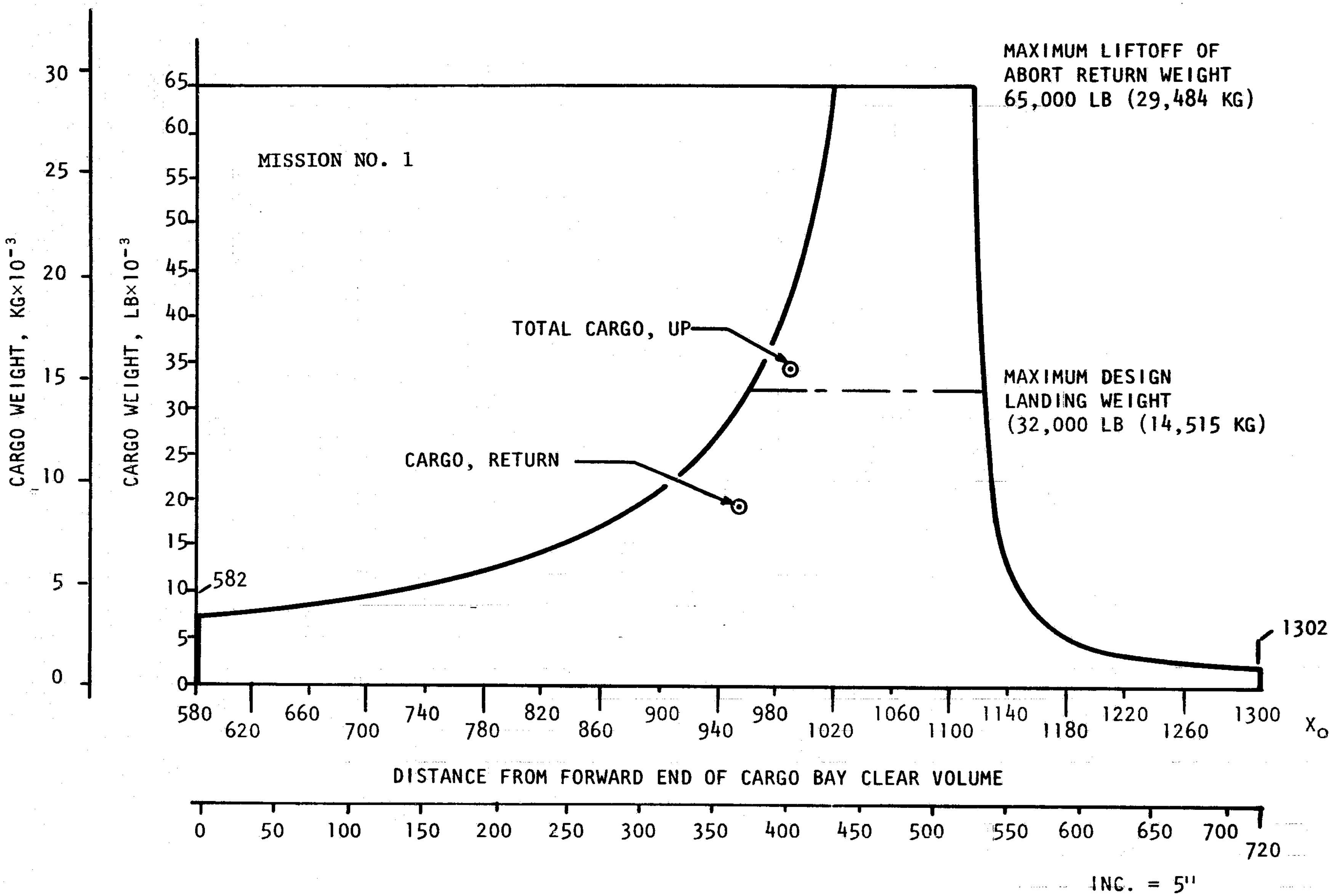

Figure 5.5-2. Cargo Center-of-Gravity Locations

6.0 SECOND CONSTRUCTION MISSION

This section describes the detailed integration of the activities for the second construction mission.

The second construction mission is characterized by installation of deployable and erectable type structures (as opposed to space fabricated). It includes installation of the system control module with deployable solar array and subsequent checkout. Rendezvous and berthing are also required.

6.1 CONSTRUCTION PLAN

The objective of the second mission plan was to install the forward support structure and aft support structure (thrust structure), the forward assembly (control module and solar array), and a TT&C antenna. Also included were assembly of the cross beam bracing struts, checkout of the electrical power and signal distribution system and measurement of the final alignment of the attachment ports on the long cross beams and the thrust structure. As for Mission 1, an attempt was made to include as many as possible of the modules and structural pieces required to complete the platform. The possible installation of RCS pods on this mission was investigated. However, the results showed the concept to be not feasible, due to weight and volume considerations

The configuration resulting from construction performed during Mission 2 is shown in Figure 6.1-1.

6.1.1 Construction Requirements

Construction requirements specific to the second mission are listed in Table 6.1-1. Initially, the orbiter must rendezvous and berth to the stabilized platform at the berthing port of the construction fixture. In order to perform the various installation activities with a single RMS arm without re-berthing, the docking interface is designed to rotate about an axis parallel to the orbiter Z axis. Installation of the two deployable truss structures was deemed reason to require an open cherry picker platform, and its use is continued for installation of bracing struts because of the wide-angle visibility advantages of the on-site EVA astronaut.

6.1.2 Construction Logic

Figure 6.1-2 depicts the logic diagram devised for the activities performed during the second mission.

The second mission has very few parallel construction activities, since each function typically engages full attention of the crew and the available construction equipment.

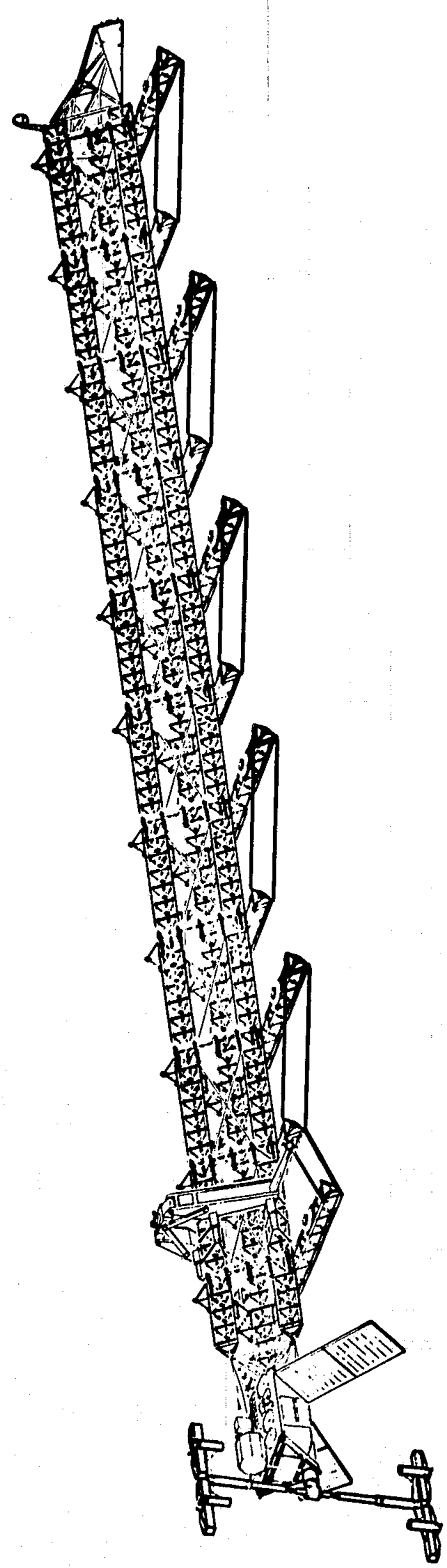

Figure 6.1-1. Configuration of the Engineering and Technology Verification Platform at the end of the Second Mission

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Table 6.1-1. Construction Requirements - Second Mission

• Provide means to safely rendezvous and berth the orbiter to the construction fixture in a position facing the opposite direction from that when the orbiter was separated at the end of the first mission.
• Provide means to deploy and install two folded support structures, one at each end of the platform.
• Provide means to install the forward assembly modules, make its electrical connections to the platform and partially deploy the solar array.
• Provide means to join bracing struts between ends of long and short cross beams.
• Provide means to check electrical distribution network continuity.
• Provide means to measure alignment of attachment ports for platform payloads and orbit transfer propulsion modules.
• Provide means for translatation of the platform and for rotation of the platform structure relative to the orbiter to assure adequate reach of an RMS arm to the forward assembly and the aft support (thrust structure).
• Provide means to install the TT&C antenna and associated electrical wiring harness.

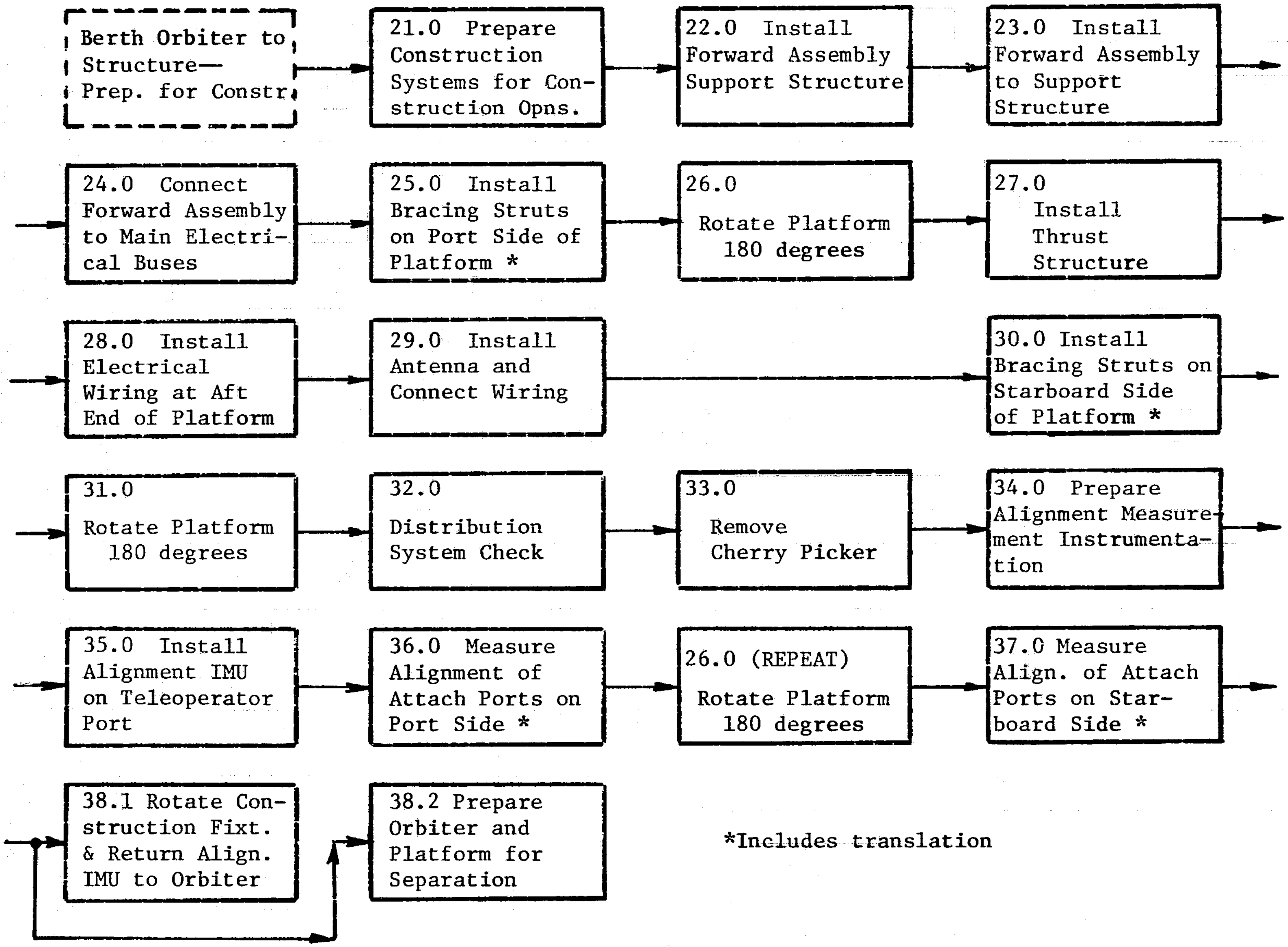

Figure 6.1-2. Logic Diagram for Construction Activities during Second Mission

6.2 CONSTRUCTION PROCESS - SECOND MISSION

The construction process during the second mission is preceded by an extensive series of burns and coast periods to achieve rendezvous with the orbiting platform. Upon achieving rendezvous, the RMS is checked out and deployed to prepare for berthing to the construction fixture. Also, a cannister which contains bracing struts is rotated out of the orbiter payload bay to the starboard side. In the process, this activity uncovers the berthing port and provides access to other stowed items. This requirement results from the selected packaging concept, and might be revised following further design trades. For example, the bracing struts could be stowed in a folded condition in order to require less payload bay length, but this would necessitate added on-orbit time to extend the struts.

Using the RMS, the orbiter berths to the construction fixture at the forward end of the ETVP with the port side of the orbiter facing the forward end. This orientation is 180^{o} from that used for the first mission. The reason for this orbiter orientation is to locate a single, standard, port-side RMS in the most favorable position for reach during the first construction task.

Following berthing of the orbiter to the construction fixture, work is begun to prepare the construction systems for operations. The libration damper RCS arms on the construction fixture are withdrawn to minimize potential obstructions for RMS transport activity or damage to the libration damper arms. The construction fixture is translated closer to the end where the forward assembly is to be installed.

The RMS then engages a stowed open cherry picker (MRWS concept) and unstows it. An EVA astronaut deploys the cherry picker and boards it.

This EVA method was selected following a review of the requirements for transport, alignment, attachment and deployment of the forward structure. The key concerns involved the dexterity needed to make electrical wiring connections across the support structure between the platform and the forward assembly (control module/solar array). Another benefit is the visibility and on-site manipulation possibilities for deploying and joining the forward structure.

The first major construction activity during the second mission is the installation of the forward assembly support structure, as depicted in Figure 6.2-1. This structure consists of a number of struts joined together by hinges so they will fold into a compact unit for ease of stowing in the orbiter bay. The folded structure is removed from the orbiter bay by the EVA astronaut using the cherry picker mounted on the end of the RMS. The support structure is transported to the forward end of the ETVP, unfolded and installed.

The next item to be installed is the forward assembly, which consists of the control module and the stowed solar array. This activity is shown in Figure 6.2-2. The forward assembly is removed from the orbiter bay, again by the EVA astronaut using the cherry picker/RMS, then installed on the support structure. A deployable tray on the control module is used to bridge between

• **INSTALL FORWARD STRUT ASSEMBLY**

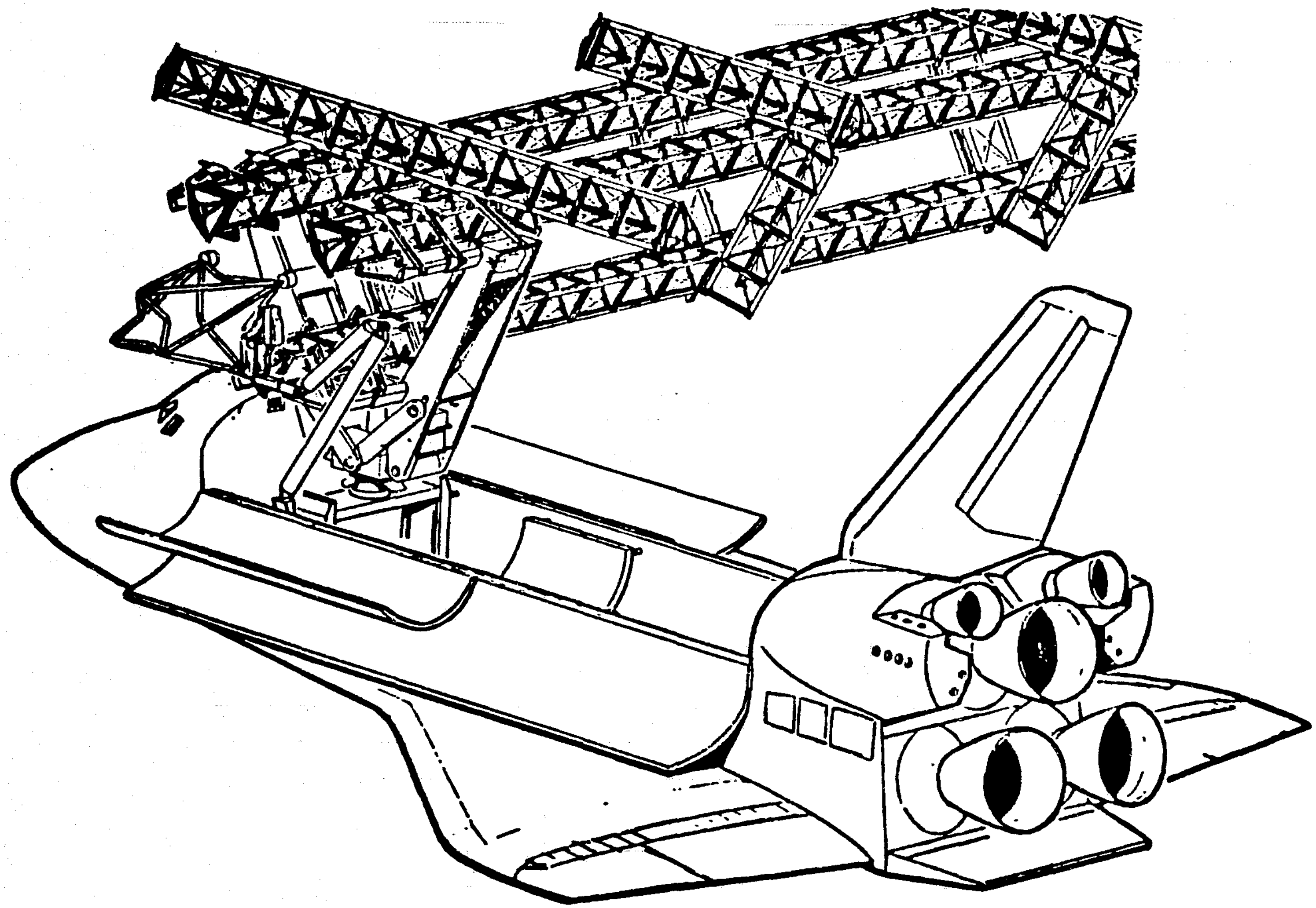

Figure 6.2-1. Installation of Forward Strut Assembly

• INSTALL SYSTEMS CONTROL MODULE

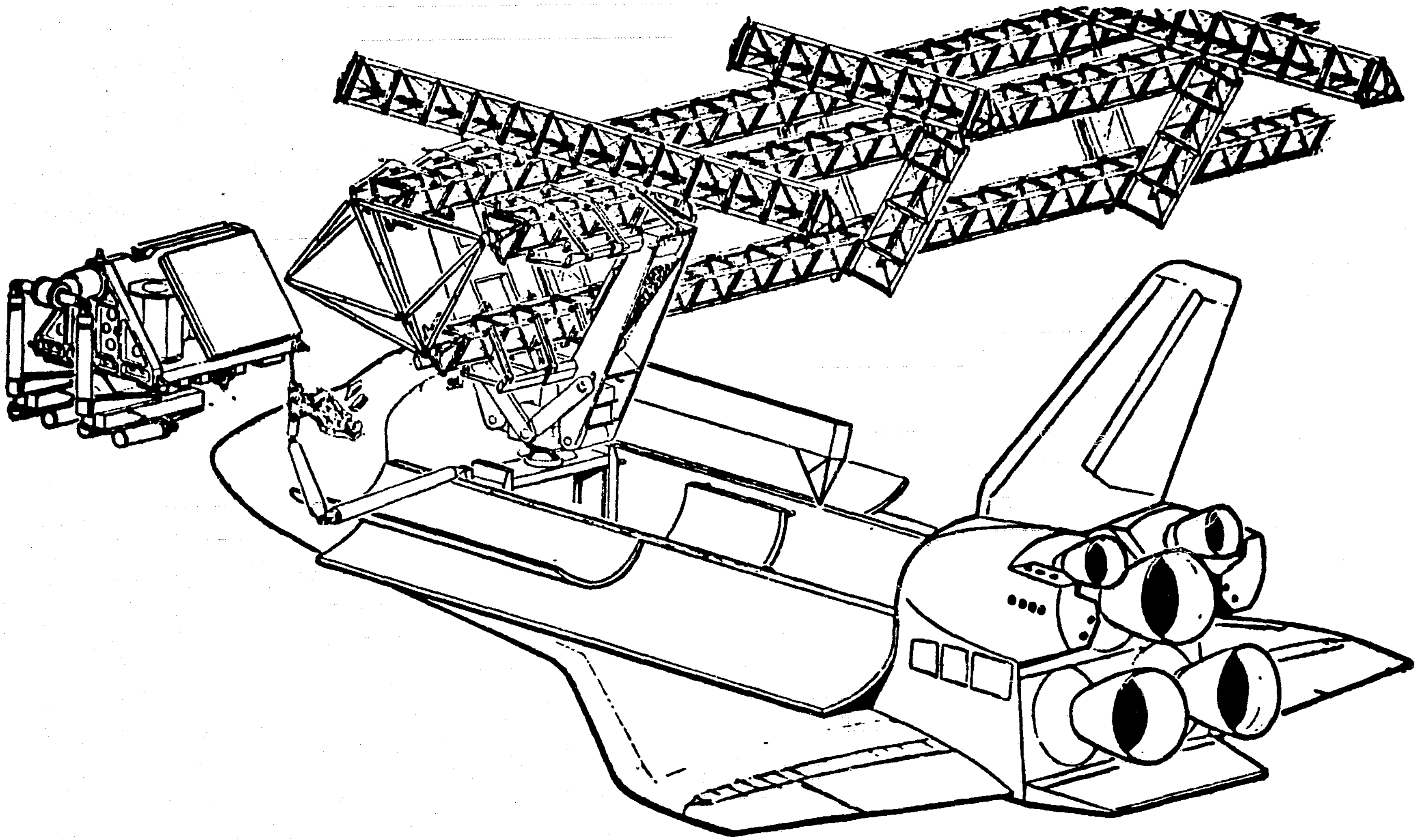

Figure 6.2-2. Installation of Systems Control Module

the control module and the ETVP and to carry all of the electrical cabling between them. This cable tray is next deployed. The joining of the pig-tailed connectors on the cable tray to the connectors on the ETVP longitudinal is performed manually by the EVA astronaut, while supported on the cherry picker.

As previously mentioned, the cannister which contains the brace struts was rotated out of the orbiter bay prior to berthing. The tray remains in this position during the entire second mission. The struts are removed one at a time from the cannister by the EVA astronaut, using the cherry picker/RMS, and installed between ends of adjacent long and short cross beams as shown in Figure 6.2-3. The port side installations on the ETVP are accomplished using a special hand-held power tool. The EVA astronaut adjusts the length of each strut as required. The orbiter translates the ETVP through the Construction Fixture #1 between each pair of installations to locate the RMS favorably for each strut set installation. At the aft end of the ETVP the orbiter rotates 180° about its Z axis, using the rotary joint in the docking port between the construction fixture and the orbiter. The purpose of this rotation is to bring the RMS into a favorable location for the next installation procedure. A rotary joint was selected because of its positive control capability and potential versatility for aiding RMS reach for payload installation.

The next task is deployment and joining of the thrust structure at the aft end of ETVP. This structure supports the three inter-orbital thrust engines and distributes their thrust into the platform structure. It consists of three separate struts and a folded assembly which contains fifteen struts hinged together. An electrical harness which is attached to the strut assembly links the three inter-orbital thrust engine attach ports to a connector located at the attach point for the apex longitudinal of the ETVP. This configuration was chosen as a compromise between ease of stowing and ease of erection and installation. The thrust structure is installed by the EVA astronaut on the cherry picker in much the same fashion that the forward support structure was installed.

The main difference between the forward and aft support structure is the need for three separate struts on the aft assembly which are installed independently before the folded strut assembly.

The main electric cable run along one of the base longitudinals of the ETVP ends in a connector at the aft end of the platform. This connection carries power and signal for the three inter-orbital thrust engines and for the TT&C antenna which is the next item to be installed.

The TT&C antenna is located at the aft end of the apex longitudinal. Therefore, it is necessary to extend the main electric cable run from the longitudinal where it currently ends, to the apex longitudinal. This special wiring and the TT&C antenna are installed by the EVA astronaut on the cherry picker/RMS as shown in Figure 6.2-4. Following this installation the EVA astronaut manually mates the connectors between the platform, the special wiring, the TT&C antenna and the thrust structure.

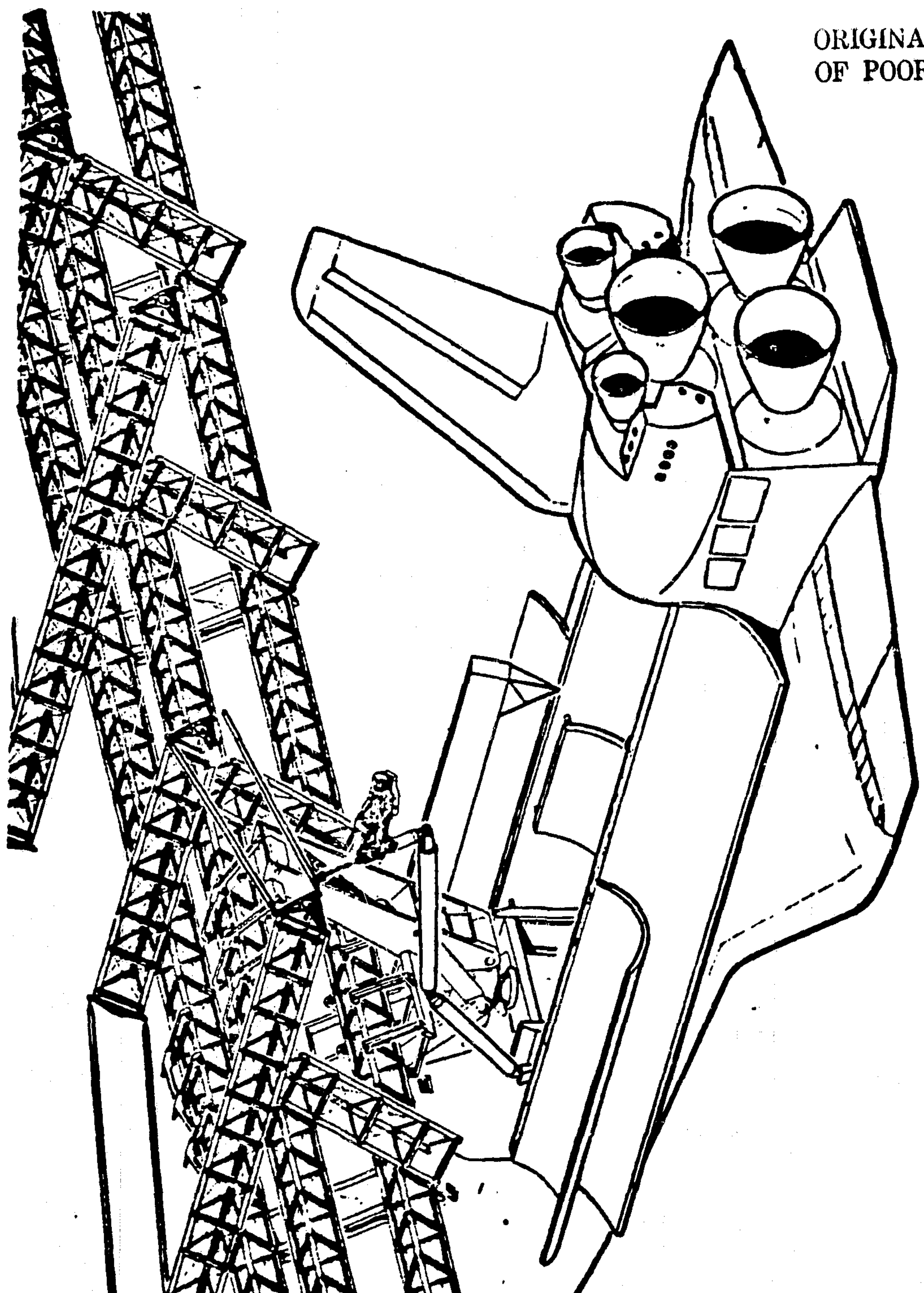

Figure 6.2-3. Installation of Cross Beam Bracing Struts

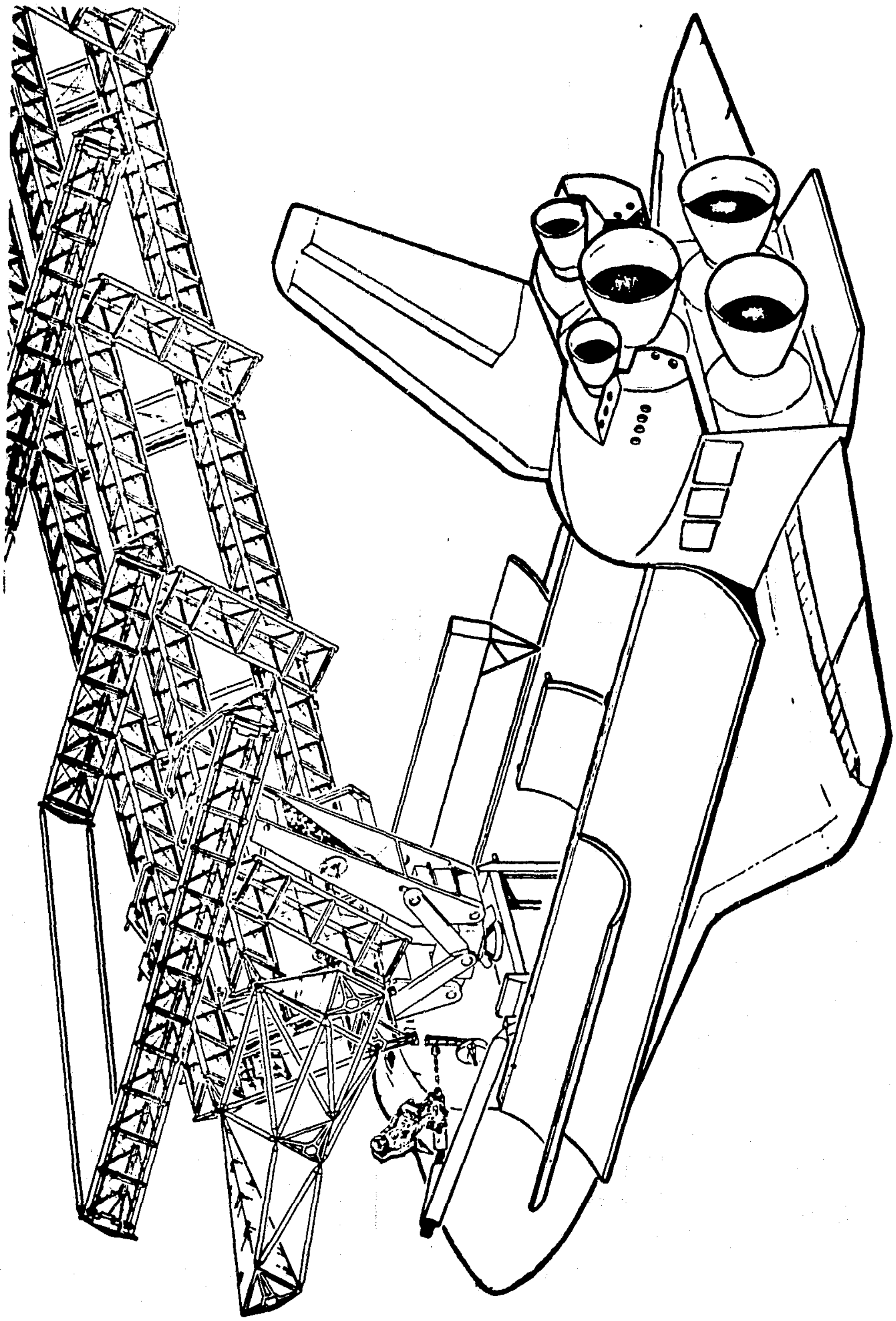

Figure 6.2-4. Installation of the TT&C Antenna Adjacent to Thrust Structure

The brace struts along the starboard side of the ETVP are installed in similar fashion to those on the port side, the orbiter translating the platform after each set of two struts is installed. After the last brace strut is installed, the orbiter again rotates 180° and is now back in the location and orientation as it was at the beginning of the second mission.

A check of the electric distribution system is performed via a cable which is dragged from the orbiter payload bay by the EVA astronaut on the cherry picker/RMS and connected into a receptacle on the control module. Concurrently with the distribution system checkout, the solar array is unfolded (but not extended) so that it can both rotate and nod. The drag cable is restowed in the orbiter on a spring return reel by the EVA astronaut on the cherry picker/RMS, as shown in Figure 6.2-5.

The EVA astronaut folds the stabilizer arm of the cherry picker and maneuvers to a foothold station close to the orbiter airlock, where he dismounts from the cherry picker and manually folds it to its stowed configuration. The astronaut enters the airlock and the cherry picker (still attached to the RMS) is moved by the RMS to its stowed location in the orbiter bay where it is stowed and disconnected from the RMS.

It is required that measurements be made of the orientation of the control module attitude reference system relative to the orientation of the attach ports for the payloads and the inter-orbital thrust engines. To accomplish this, two calibrated IMU's are used. Removed from a special baseline mounting fixture in the orbiter bay by the RMS, the first IMU is installed on the control module where it remains while the second IMU is installed in turn at each of the attach ports to be measured, such as indicated in Figure 6.2-6. During this procedure the orbiter translates along the port side of the ETVP, rotates 180° at the aft end and returns along the starboard side.

The IMU's are battery powered and each contains a system for continuously recording time and orientation. When all of the attach ports have been measured the two IMU's are returned by the RMS to the baseline mounting fixture. Subsequent to the landing of the orbiter, the IMU records are examined to calculate the required measurements.

Following the completion of the construction tasks of Mission 2, the orbiter and the ETVP prepare for separation. On the construction fixture, the libration damper arms are extended and the ETVP attitude control system is activated. The orbiter separates from the construction fixture/ETVP at the berthing port, using the RMS. The berthing port on the orbiter is retracted and the cannister for bracing struts is then stowed. The orbiter enters a barbecue phase and waiting period for opportunity to descend and land at Kennedy Space Center.

Figure 6.2-7 graphically summarizes the assembly sequence for the second mission, with particular emphasis on the relative rotations of the platform with respect to the orbiter. Since two large masses with significant moments of inertia are involved, it is not obvious which is most easily thought of as the reference "stable" mass. In Figure 6.2-7, the platform is used as the reference mass.

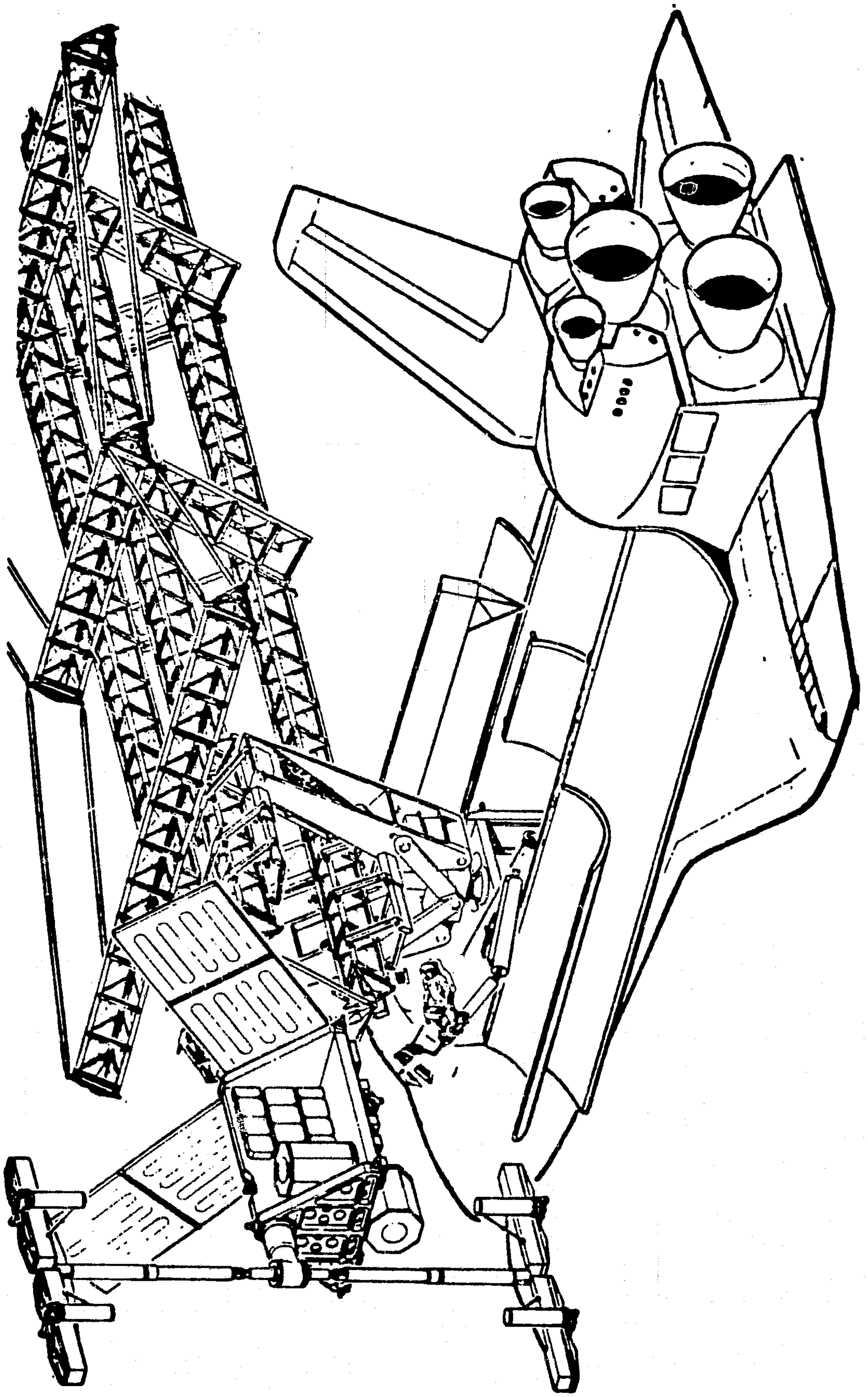

Figure 6.2-5. Perform Electrical Continuity Checks

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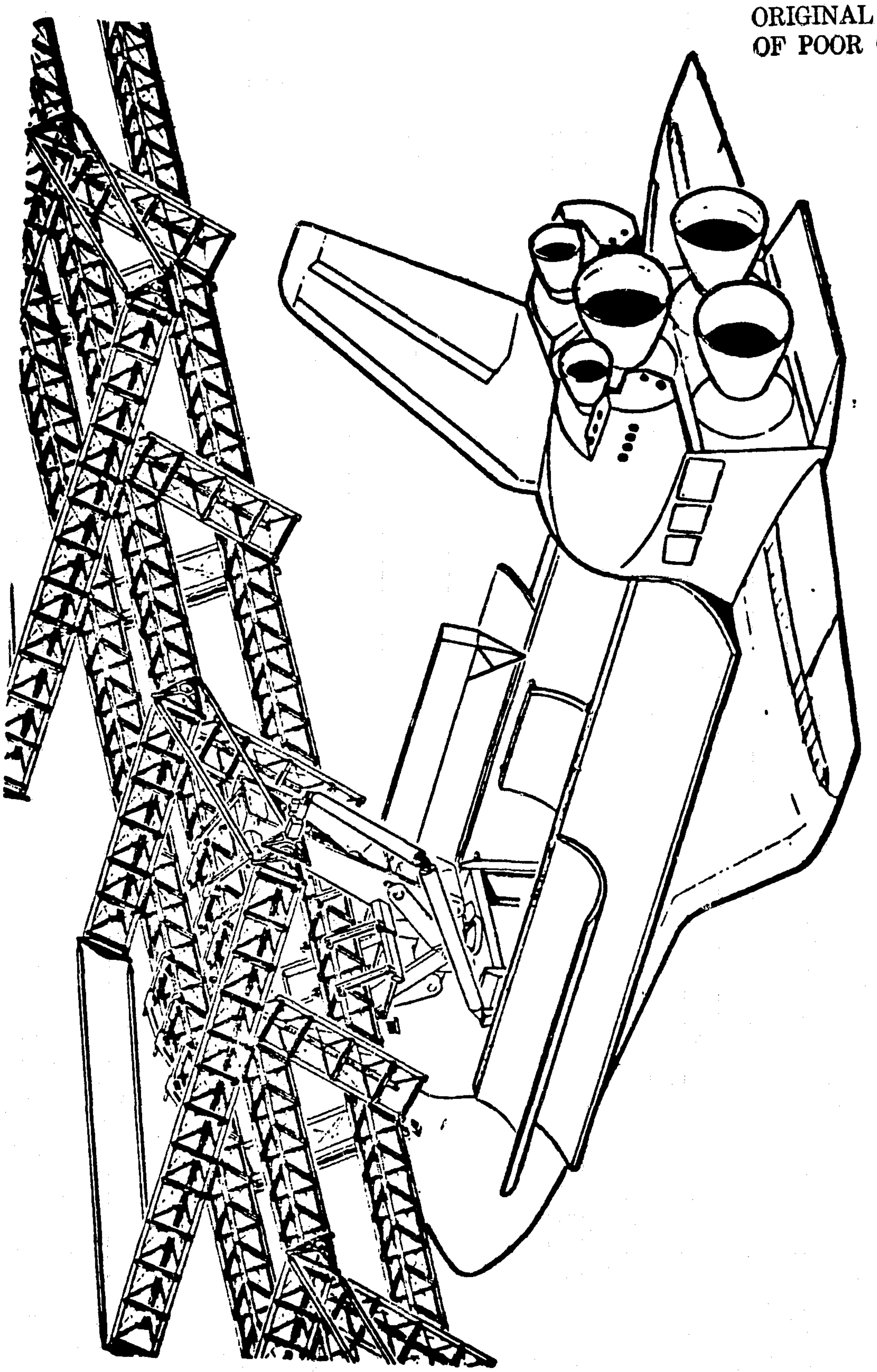
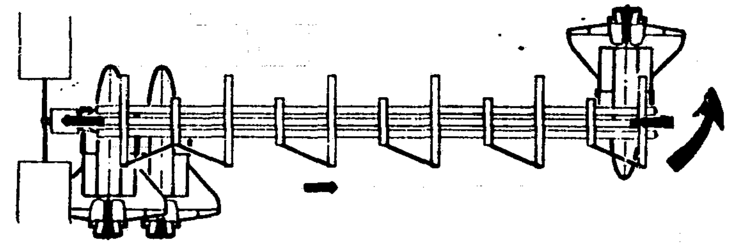
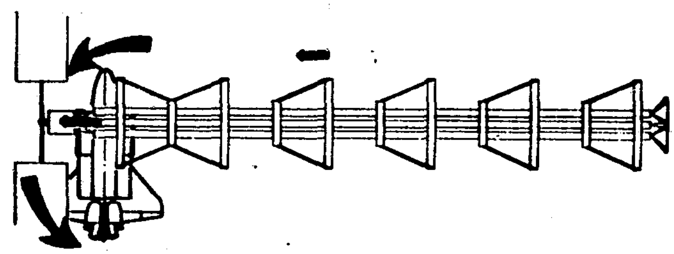


Figure 6.2-6. Measure Structural Misalignments

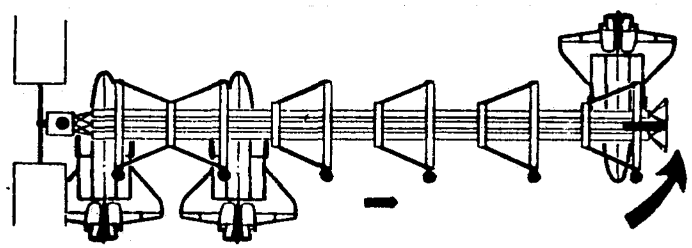
- INSTALL SCM SUPPORT STRUCTURE
- INSTALL SCM
- INSTALL BRACING STRUTS
- ROTATE ORBITER



- INSTALL THRUST STRUCTURE
- INSTALL BRACING STRUTS
- ROTATE ORBITER
- CHECK-OUT ELECTRICAL LINE CONTINUITY



- INSTALL ALIGNMENT PACKAGE ON SCM
- SEQUENTIALLY INSTALL ALIGNMENT PACKAGE ON ATTACH PORTS
- ROTATE ORBITER



- SEQUENTIALLY INSTALL ALIGNMENT PACKAGE ON THRUST STRUCTURE O.T. PROPULSION MODULE PORTS
- SEQUENTIALLY INSTALL ALIGNMENT PACKAGE ON REMAINING ATTACH PORTS
- ROTATE ORBITER
- REMOVE & STOW ALIGNMENT PACKAGES

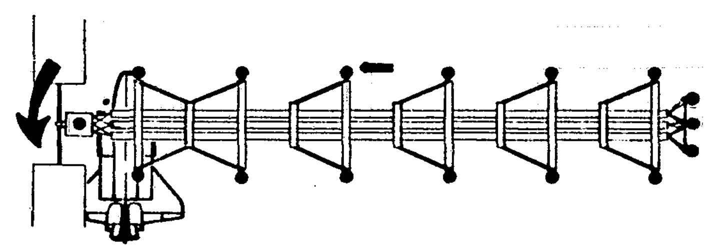


Figure 6.2-7. Second Mission Assembly Sequence

6.3 CONSTRUCTION ACTIVITY ANALYSES

General comments in Section 5.3 describing the Construction Activity Analysis sheets and the process of analysis are also applicable to the analysis of the second mission. Some differences appear in the number and scope of the activities described. There are fewer documents, since there are fewer different types of parts handled, and there are few parallel operations.

The assemblage of Construction Activity Data Sheets for the second mission comprise information about a higher percentage of the total mission time than was the case for the first mission. Many of the first mission sheets described only selected samples, usually the first, of a series which was repeated many times. In the second mission there is only one such repetitious activity handled in that manner (No. 26.0 - Rotate Platform 180°). However, note that there is one such rotation which is described as part of activity 38.1.

Copies of Construction Activity Data sheets for the second mission appear in Appendix B, and are numbered serially from 21.0 through 38.2.

6.4 INTEGRATION ANALYSIS

The integration analysis for Mission 2 was performed on a complete, end-to-end basis for both the activity timeline and the power profile. Otherwise, the objectives and end products of the integration analyses were essentially the same as for the first mission. Information derived during analysis of the first mission permitted better planning and format arrangement of analytical forms, which facilitated the analysis. Also, the general absence of overlapping activities made analysis much more straight forward and simpler. Results of the analyses are discussed in the following sections.

6.4.1 Timelines

The integrated activity timeline analysis for Mission 2 is presented in Figure 6.4-1. Although fewer different activities are involved, the construction time is noticeably longer for Mission 2 (59.45 hrs. without design margin) as compared to 42.52 for the first mission. Note that the elapsed time for construction includes two delay periods which follow a rotation of the platform with respect to the orbiter. One of these is quite long, approximately 4.4 hours. In calculating the 50% design margin for construction activity these delays were not considered. That is, the 50% design margin of 27.3 hours is based on actual construction time of 54.6 hours, not on the elapsed time from setup to shutdown.

The delay mentioned above raises a general question peculiar to space construction schedule planning: Should EVA astronauts be left outside during extensive delays for translation, rotation or checkout, etc., in which they have no duty requirements? If they remain outside, considerable boredom and questionable exposure to hazards is incurred. If brought inside, they incur a possible requirement for extensive suit checkout prior to egress, plus the

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ACTIVITY

21.0	PREPARE CONSTRUCTION SYSTEM
22.0	INSTALL FWD. SUPPORT STRUCTURE
23.0	INSTALL FWD. ASSEMBLY
24.0	CONNECT FWD. ASSY. ELECTRICAL
25.0	INSTALL STRUTS - PORT
26.0	ROTATE +180°
27.0	INSTALL THRUST STRUCTURE
28.0	INSTALL SPECIAL WIRING
29.0	CONNECT ANTENNA & WIRING
30.0	INSTALL STRUTS - STARBOARD
31.0	ROTATE -180°
32.0	DISTRIBUTION SYSTEM CHECK
33.0	REMOVE CHERRY PICKER
34.0	PREPARE ALIGNMENT INSTRUMENT
35.0	INSTALL ALIGNMENT IMU
36.0	PERFORM ALIGNMENT - PORT
37.0	PERFORM ALIGNMENT - STARBOARD
38.1	RETURN IMU TO ORBITER
38.2	PREPARE FOR SEPARATION
	DELAY
	EVA ASTRONAUT NO. 1 - EGRESS, REST, LUNCH & INGRES
	EVA ASTRONAUT NO. 2 - EGRESS, REST, LUNCH & INGRES
	EVA ASTRONAUT NO. 3 - EGRESS, REST, LUNCH & INGRES

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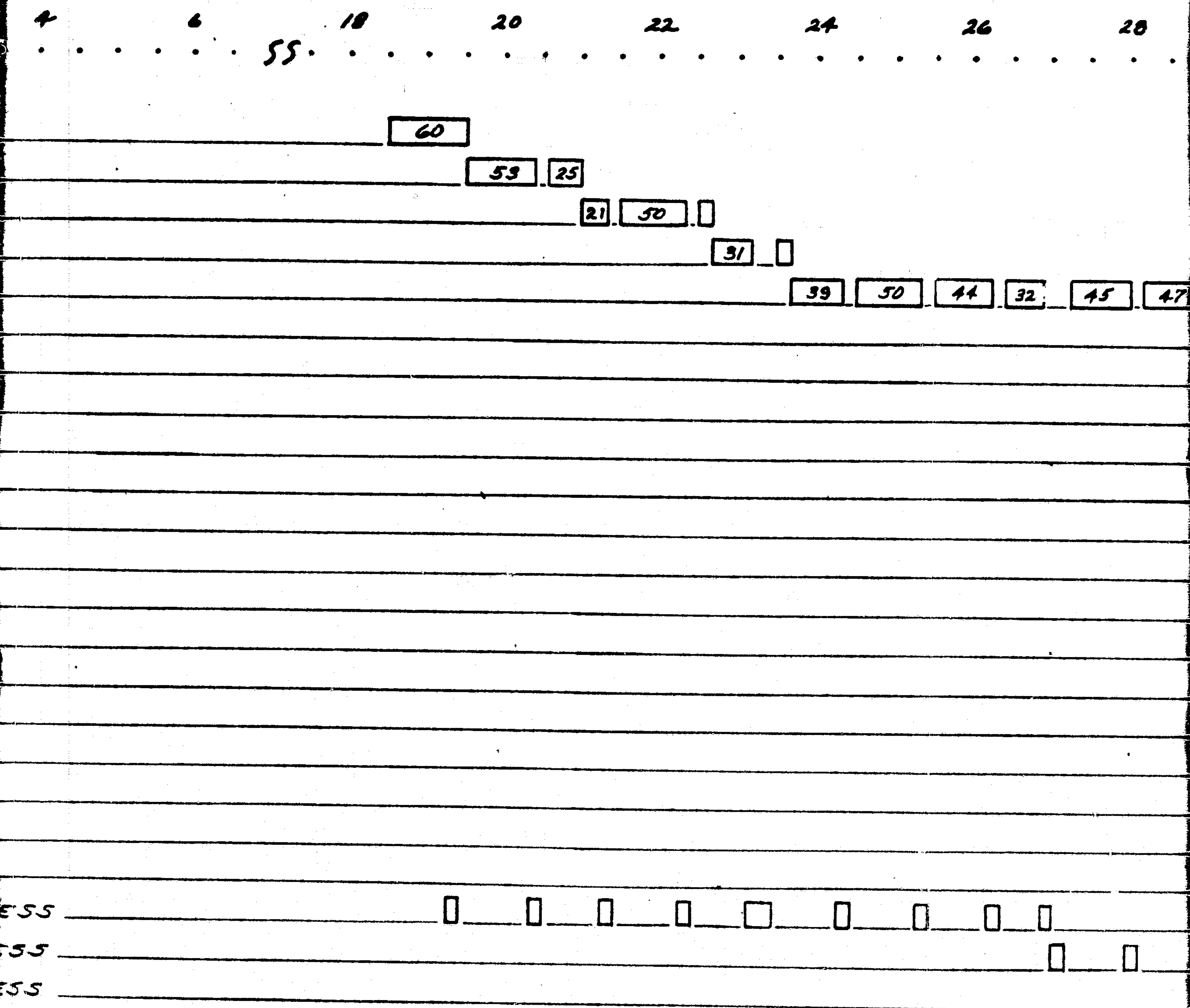

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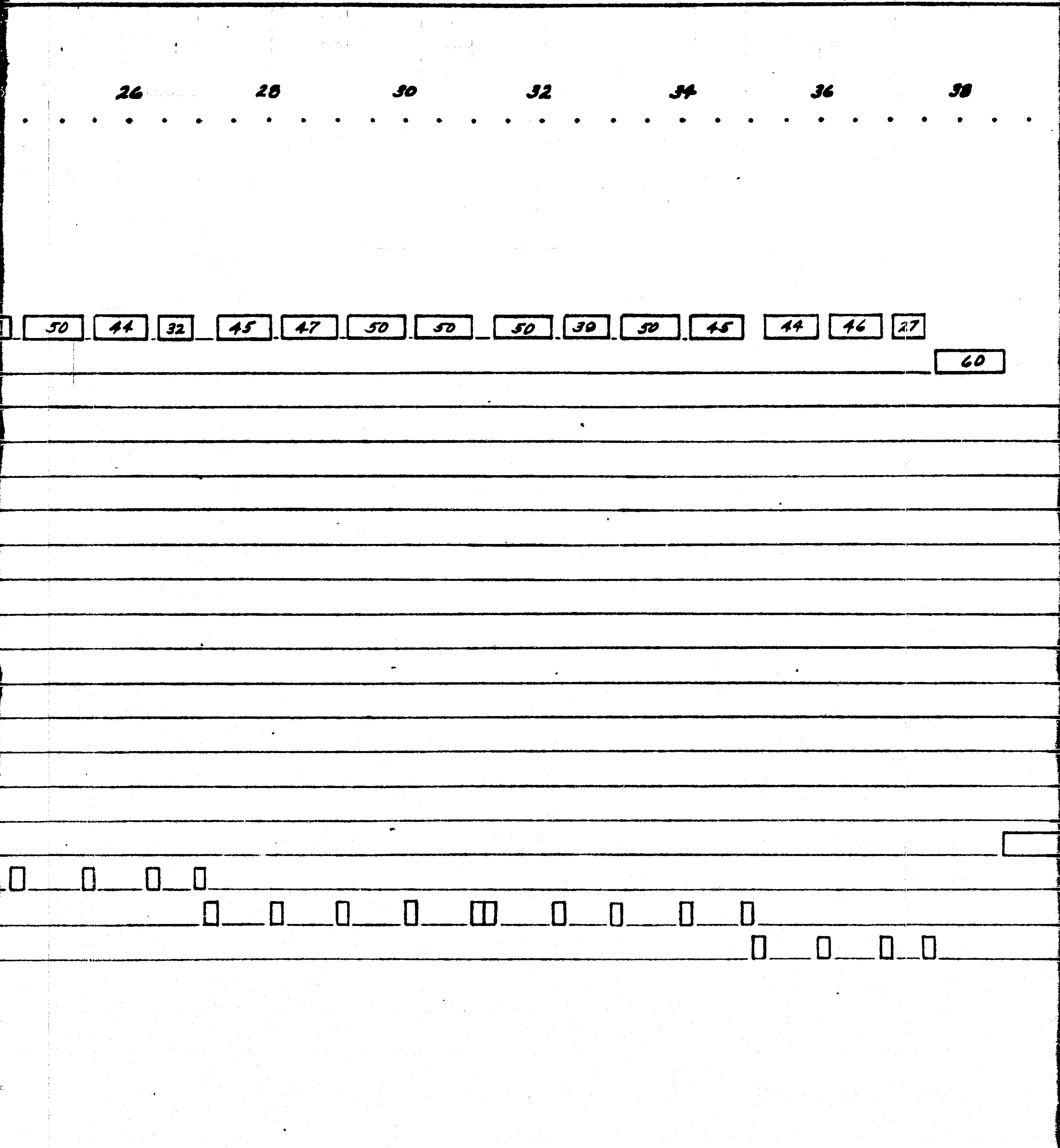

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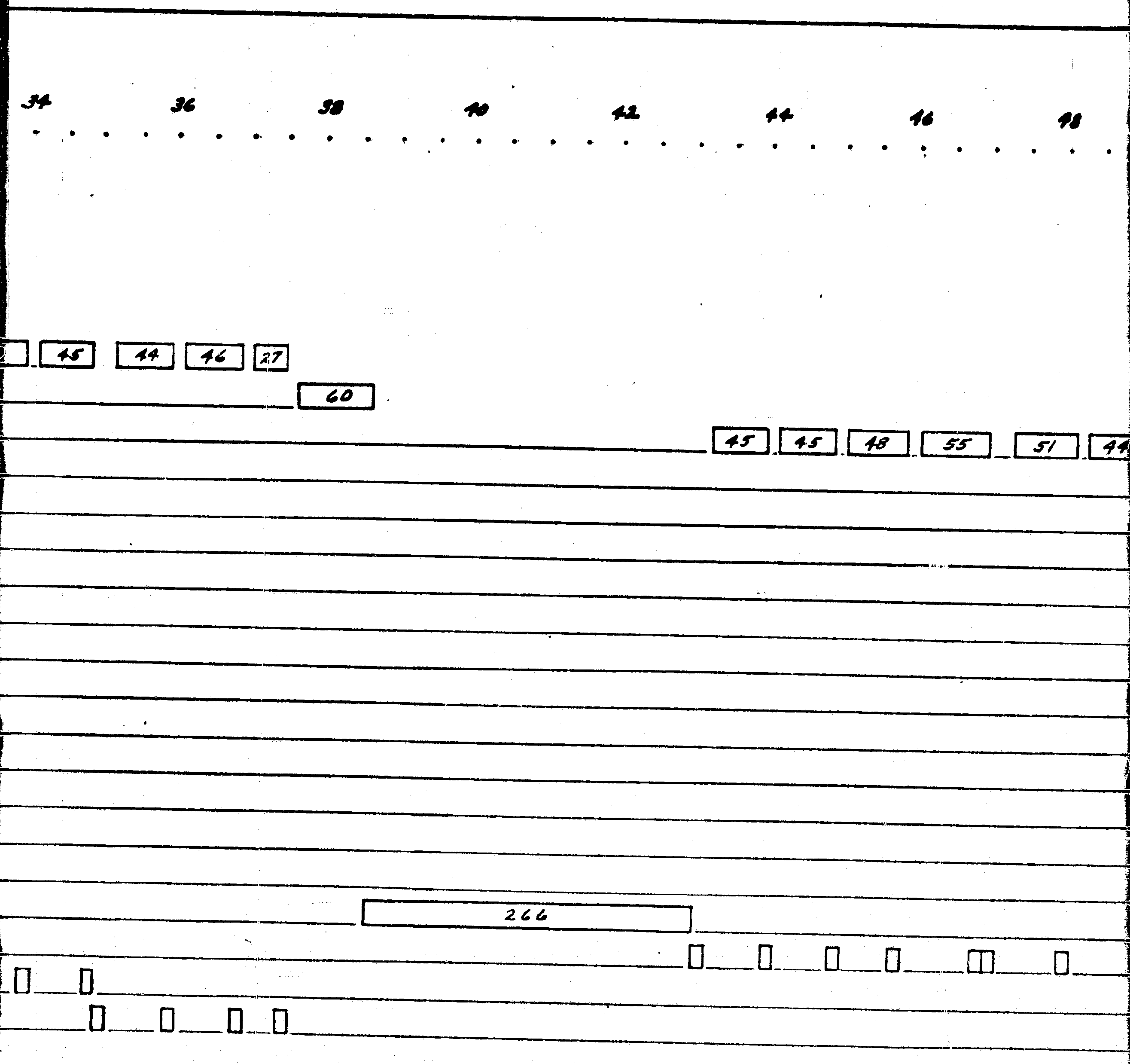

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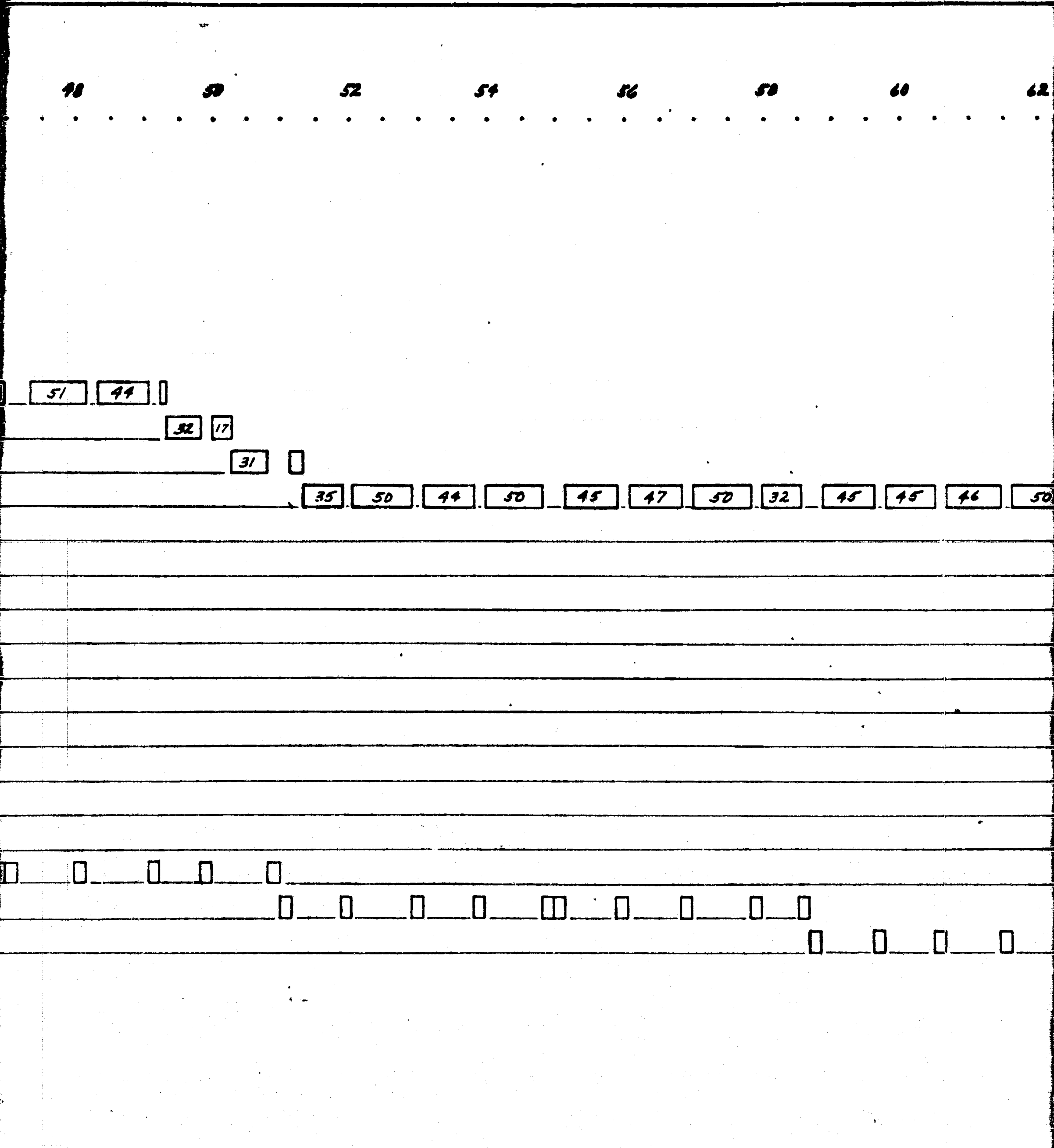

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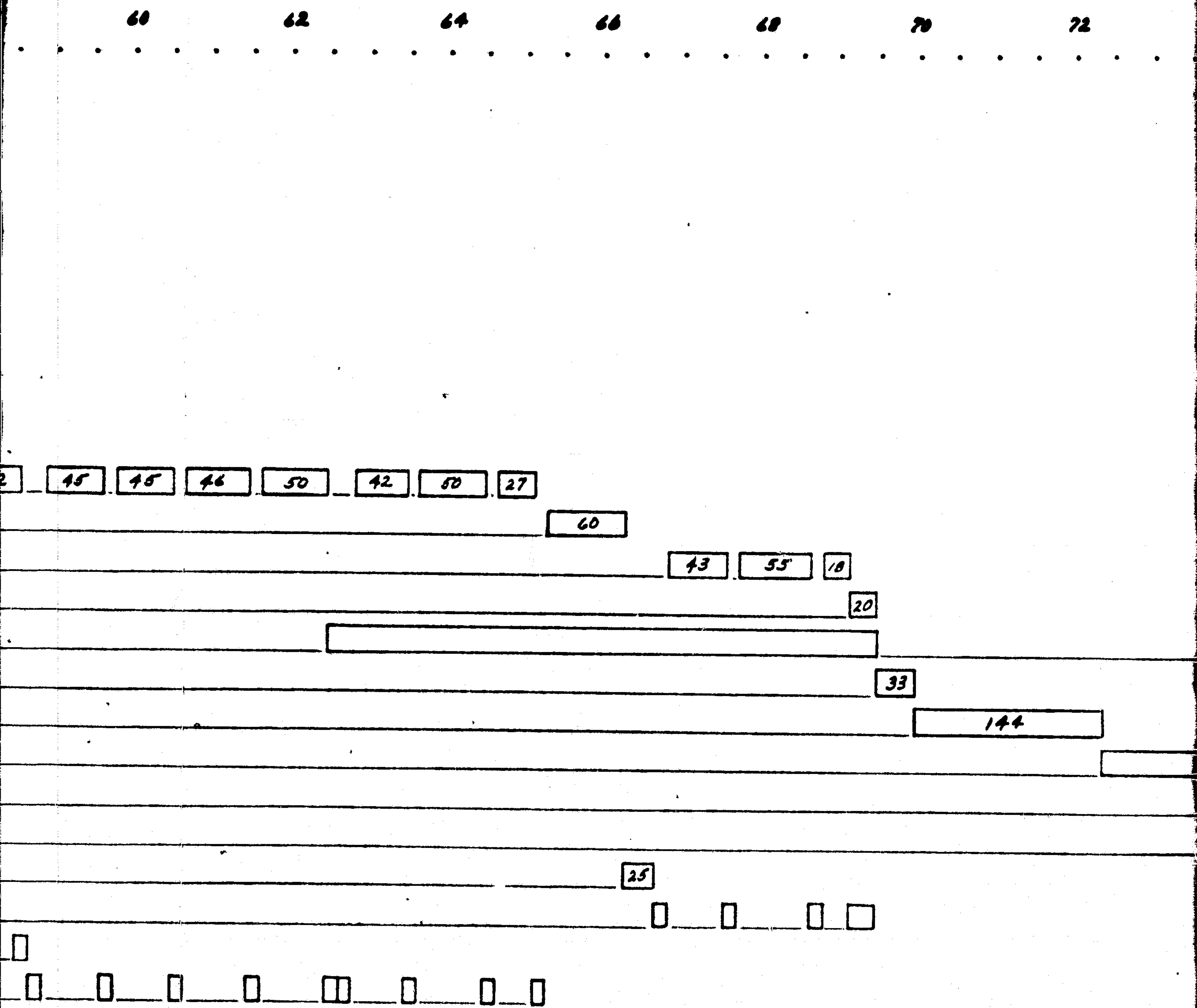

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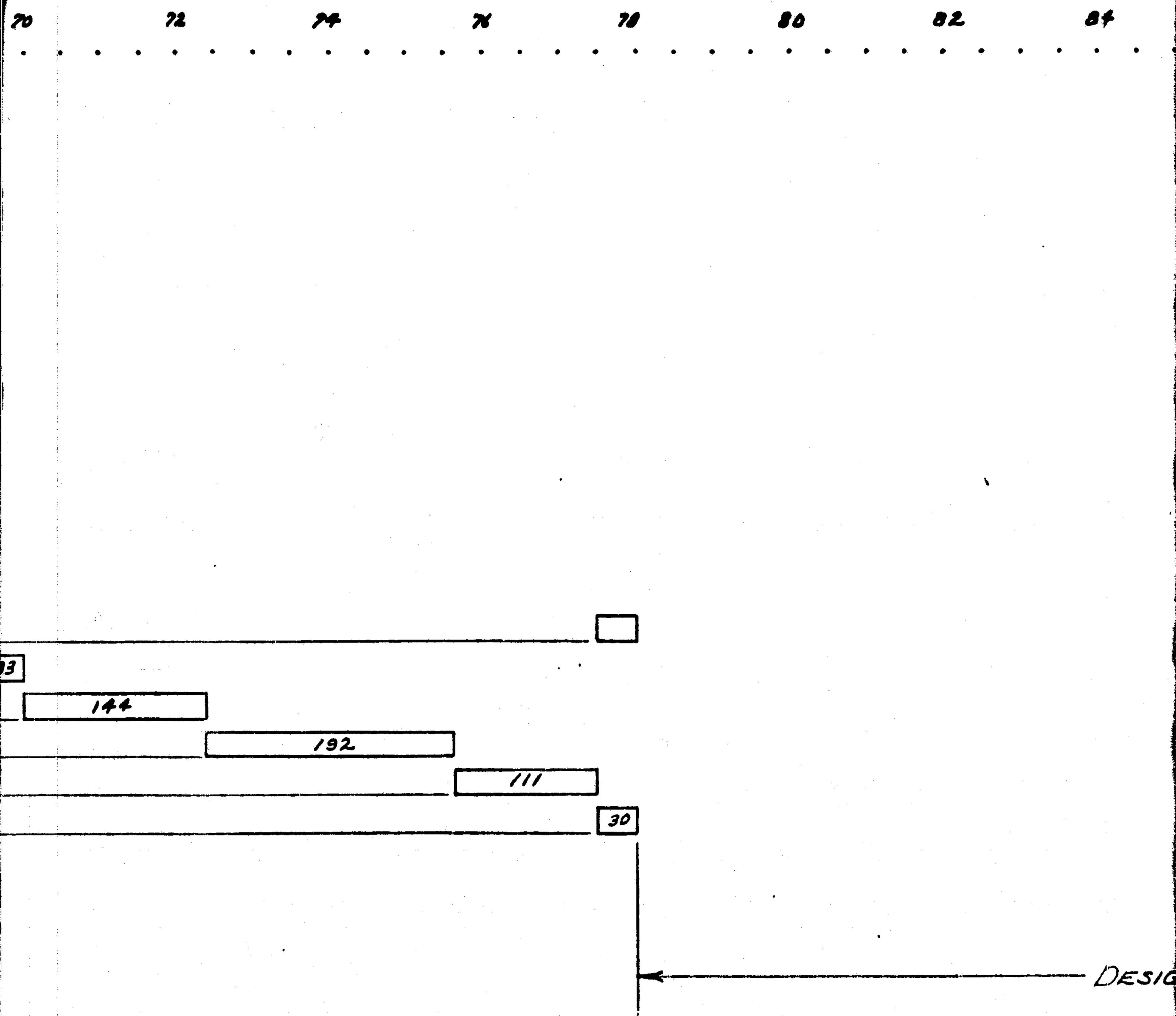

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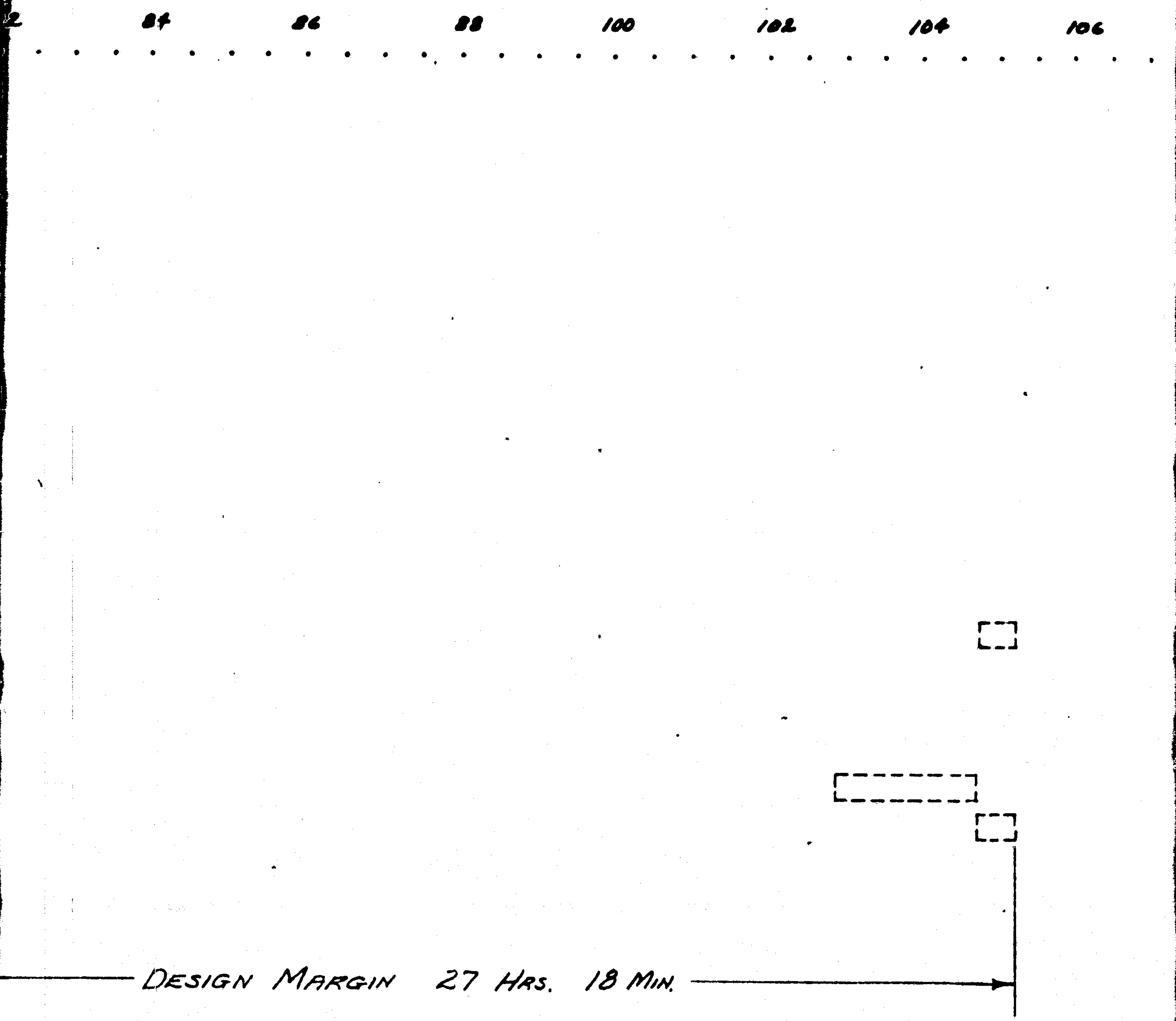

Figure 6.4-1. Integrated

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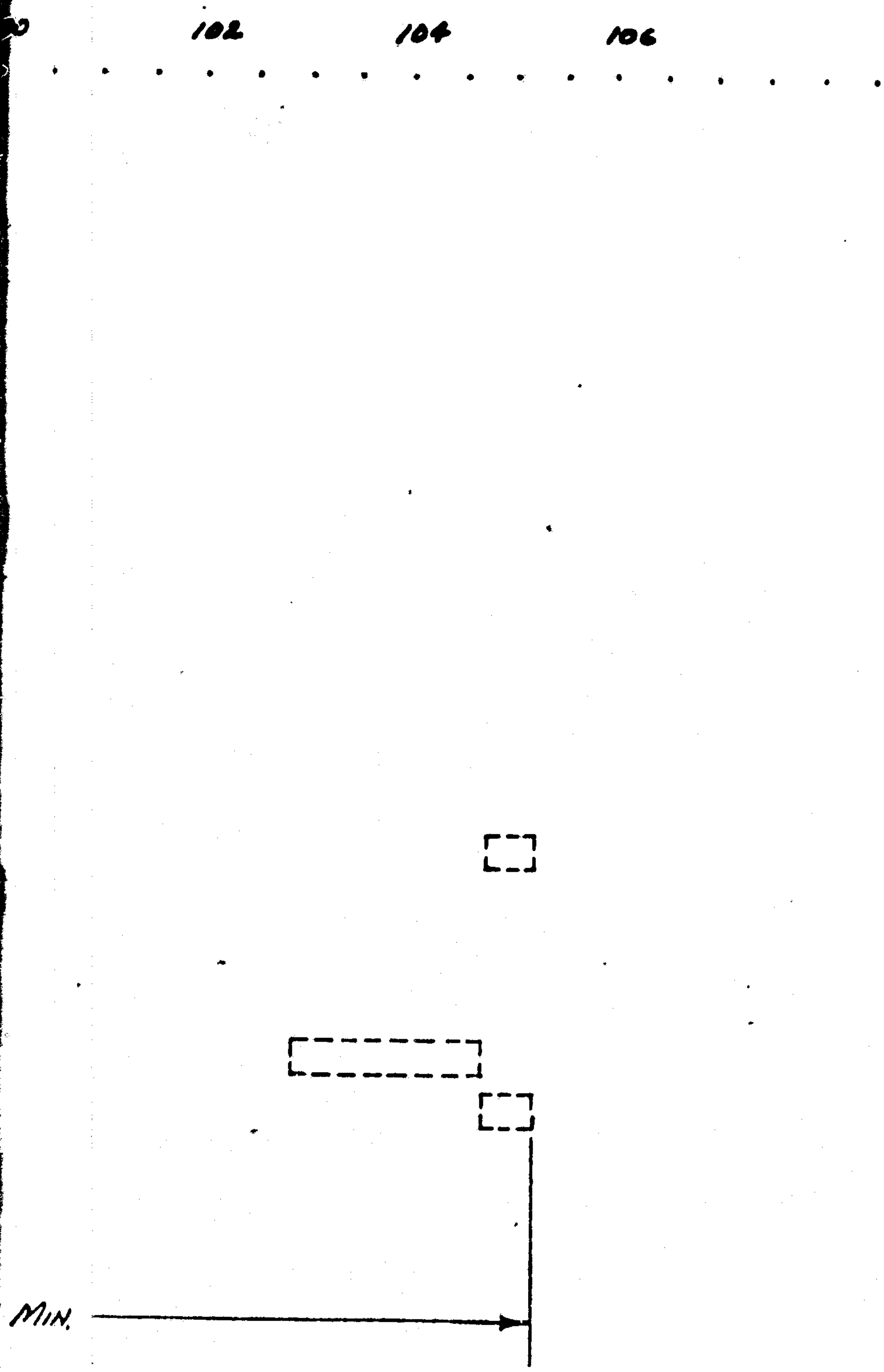

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Figure 6.4-1. Integrated Activity Timeline—Mission 2

fatigue and psychological adjustment of a shutdown activity followed by a startup and return to somewhat hazardous duty in the same day. On the other side of the argument is the fact that a major overhead cost and effort is required to suitup for each EVA period which is likely to be limited in number of work hours both by the life support system and by crew fatigue. Policy decisions need to be formulated to cover such occurrences which happen near the middle of a given EVA work shift. In the case of this analysis, the results probably are not crucial to costs or to total time on orbit, but they may be in actual work conditions in the future.

During the early portion of the mission, some of the activities are obviously interrupted by crew rest periods. This factor was not so obvious in the Mission 1 activity timeline, due to the overlapping and simultaneous nature of the activities.

6.4.2 Crew Activity

Crew activity scheduling for Mission 2 is similar to that for Mission 1. Three teams of two persons each are presumed to be operating for three shifts of eight hours per day during EVA activities. Thus, a crew of six is required to accomplish the mission using the schedule shown. Suit pressure and pre-breathing issues are similar.

Six EVA shifts of actual work are required. However, the delays mentioned above (Section 6.4.1) require suiting up and repressurizations for seven shifts of work, two of which are of short duration.

6.4.3 Lighting and TV Camera Requirements

The second and third missions use many of the same lamps and TV cameras locations provided for the first mission. However, their uses will be different. For example, in the second mission the cameras and lights mounted on Construction Station No. 1 will be useful for observation of the grappling, transport and installation of the forward and aft support structure assemblies, the forward assembly (control module/solar array), the struts, the alignment measurement device, and the electrical system checkout cable. The tilt and pan mechanisms provided for the TV camera and lamp units offer desirable requisite versatility for these added functions. The orbiter payload bay lamps again are used for helping grapple and remove items or for replacing them into the bay as before, but no assembly actually takes place in the bay.

Significant changes include removal of the beam builder lamps and camera and impact of the modified cherry picker on the RMS. The wrist camera and lamp on the RMS will be of little use when the cherry picker is joined to the standard end effector. Instead, the eyes of the EVA astronaut and the cherry picker lamps will perform the functions required.

The processes and viewing angles required for installing the forward and aft support structure and the forward assembly have conflicting needs for lighting as the activity proceeds. For example, the lamps on the construction fixture yoke are helpful in grappling, removing from the payload bay and trans-

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porting. However; when it comes to detailed joining operations, these lights will probably cause unacceptable glare and shadows on the key interfaces because of their location. Therefore, the construction procedure calls for turning these lamps off (or turning them aside) and relying on the cherry picker (or RMS wrist lamp) for illuminating the detail final joining or adjusting operations. Whenever these activities can be performed in daylight there is further opportunity to turn off the lamps mounted on the construction fixture (however, such reductions are not included in power and energy calculations).

The multiplicity of TV camera locations permits the crew in the cabin to view nearly all operations and to help guide the lamps to illuminate the scene effectively. Active cooperation and verbal communication between the EVA and IVA operator are necessary for illuminating cherry picker operations effectively and for avoiding counter-productive glare and shadow conditions.

Figure 6.4-2 summarizes the key locations for lights and TV cameras for the second mission. The figure also suffices to describe these items for the third mission which is described in Section 7.0.

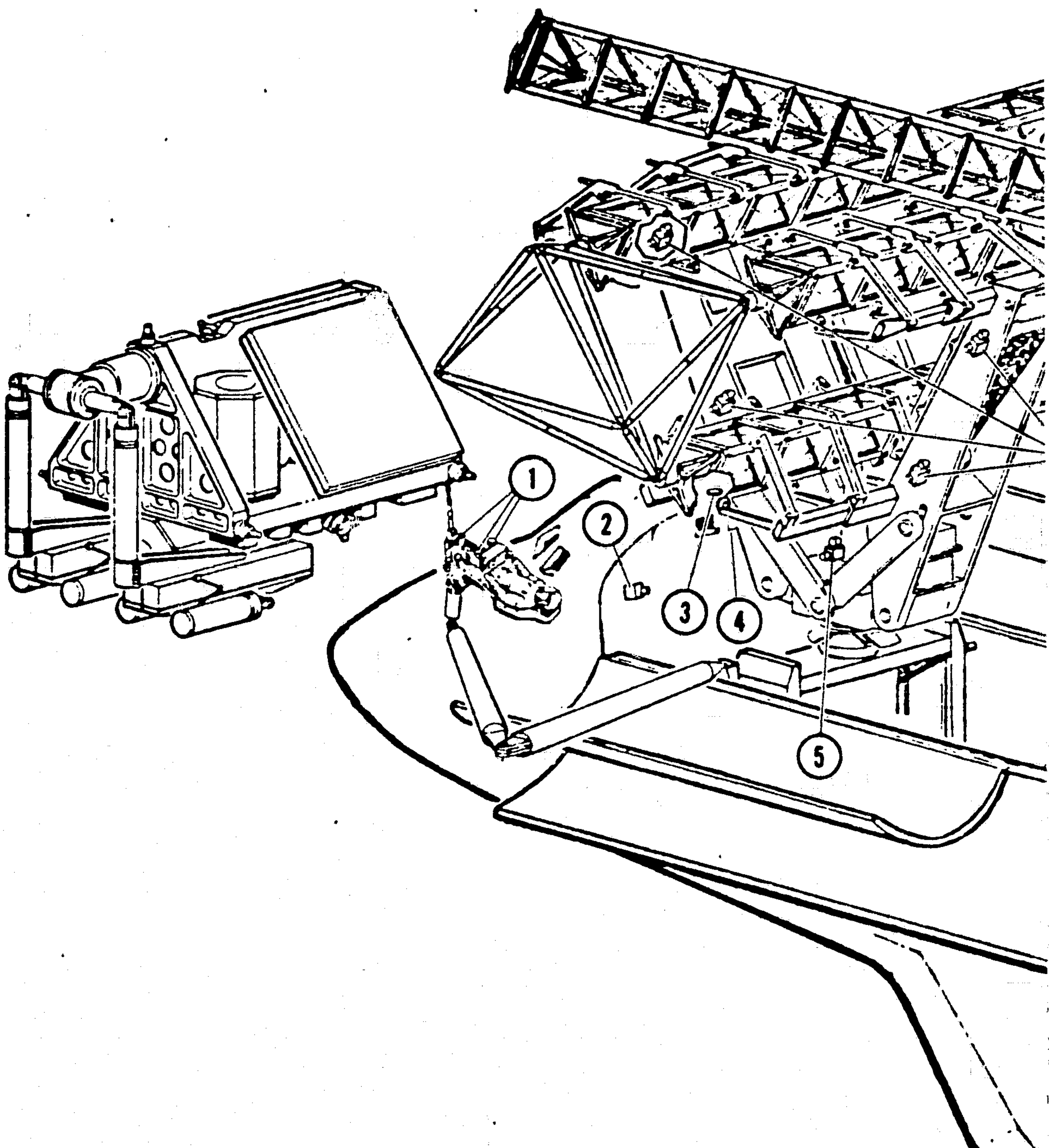
In general, the power demand for lighting during the second mission is about 45% of the total, a greater percentage of total construction power than in the first mission. This result is primarily due to lack of power demands for beam fabrication, while other major activities (lighting and transport/assembly) are similar in power levels to those for the first mission.

6.4.4 Power Demand Analysis

The key assumptions and estimating procedures for the power and energy analysis of the second mission were largely the same as for the first mission. A major difference was the lack of a beam builder machine. Another significant difference was that the entire mission was considered in an end-to-end analysis, including crew rest periods as they occurred in chronological time.

Figure 6.4-3 presents the complete power profile for the second mission. Although the second mission is longer than the first, the complexity of analysis was not as great, since there are few parallel and overlapping operations. The resulting profiles of peak and average power reflect less frequent variations of a smaller magnitude than for the first mission. In addition, there was a benefit to the analysts in learning from the analysis of the first mission. This learning resulted in more complete and rapid analysis techniques.

The average requirements for power during the second mission are significantly lower than for the first. The key factor which explains this reduction is the lack of heating requirements for forming beams or joining beams together. The other major factors which are present in both Mission 1 and Mission 2 are the RMS and the lights.



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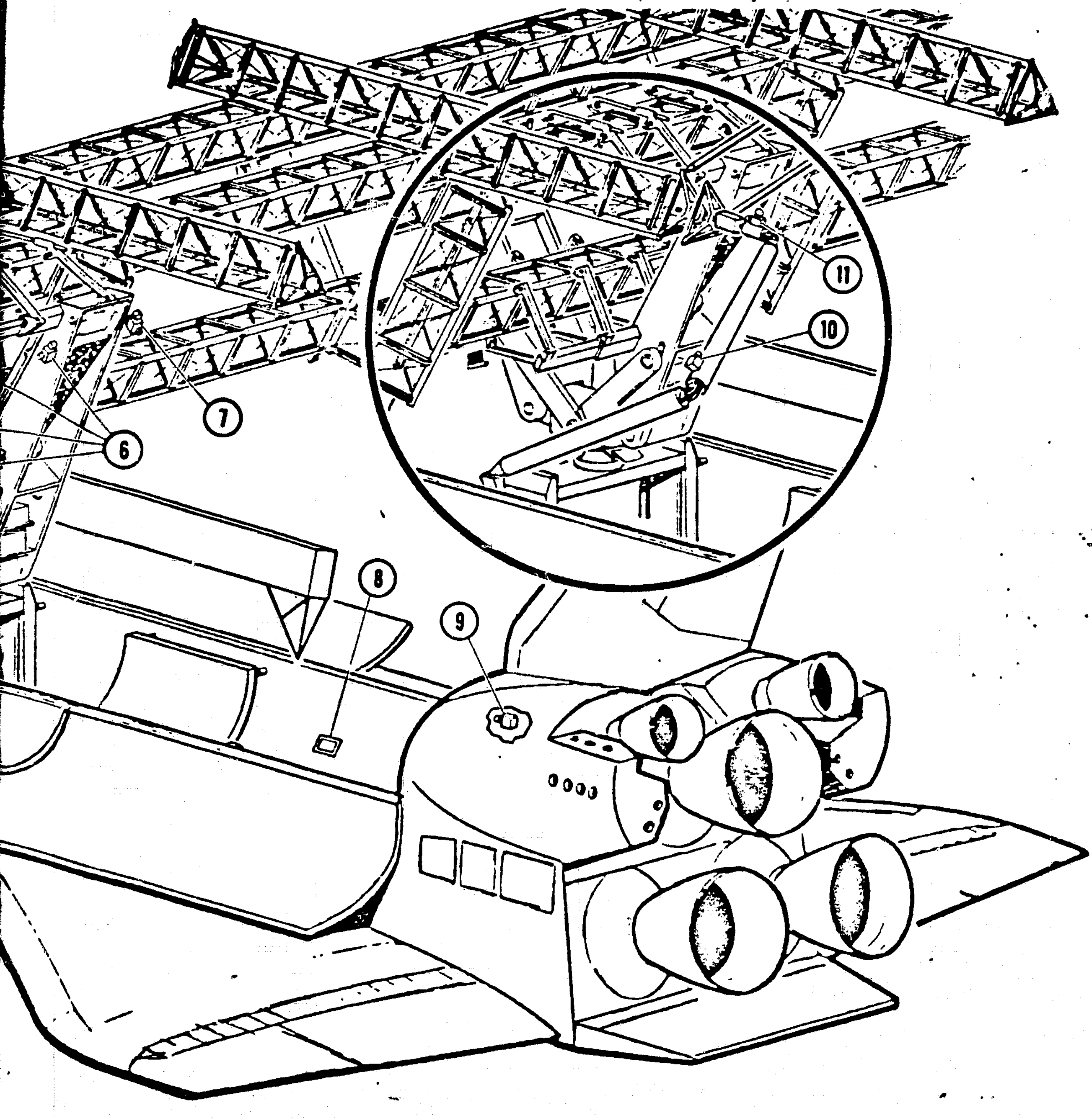

ITEM NO.
(1)
(2)
(3)
(4)
(5)
(6)

NOTES

(a)
(b)
(c)
(d)

ITEM NO.	DESCRIPTION—CHARACTERISTICS/USAGE	PEAK POWER
(1)	THREE 60-W INCANDESCENT LAMPS MOUNTED ON ADJUSTABLE BRACKETS OR STANCHIONS OF MODIFIED OPEN CHERRY PICKER (OCP) (STANDARD—PER MRWS DEVELOPMENT PLAN). PURPOSE—DETAILED ASSEMBLY, INSTALLATION ADJUSTMENT, AND INSPECTION OPERATIONS BY EVA OPERATOR. ALSO ASSISTS IN GRAPPLING WITH STABILIZER/MANIPULATOR ARM ON OCP.	0.180
(2)	ONE TV CAMERA UNIT (STANDARD ORBITER ITEM) WITH TILT AND PAN MOUNT. LOCATION—FORWARD BULKHEAD OF ORBITER PAYLOAD BAY. PURPOSE (FOR CONSTRUCTION)—ASSIST IN OBSERVATION OF CHERRY PICKER AND RMS OPERATIONS AT FORWARD END OF ETVP.	0.247
(3)	ONE ORBITER DOCKING LAMP (STANDARD). LOCATION—BETWEEN DOCKING WINDOWS ON UPPER SURFACE OF CABIN, FIXED, POINTING UPWARD. PURPOSE—BERTHING AND SEPARATION OF ORBITER FROM CONSTRUCTION FIXTURE	0.200
(4)	ONE ORBITER PAYLOAD BAY LAMP, METAL HALIDE TYPE, FIXED. LOCATION—FORWARD BULKHEAD OF ORBITER PAYLOAD BAY, BETWEEN WINDOWS. PURPOSE (FOR CONSTRUCTION)—ASSIST EVA EGRESS/INGRESS AND TRANSVERSE TO CHERRY PICKER MOUNTING POINT.	0.200
(5)	ONE INCANDESCENT FLOOD LAMP AND TV CAMERA FIXED TOGETHER ON TILT/PAN MOUNT. LOCATION—LOWER CROSSBRIDGE OF BUILDING FIXTURE YOKE. PURPOSE—ASSIST IN OBSERVATION OF EVA ASTRONAUT, MONITOR TRANSLATION OF ETVP THROUGH BUILDING FIXTURE.	0.247
(6)	FOUR LAMP AND TV UNITS SIMILAR TO (5) (EACH 0.247 PEAK POWER). LOCATION—SIDE OF BUILDING FIXTURE YOKE, FACING FORWARD END OF ETVP, DISTRIBUTED AS SHOWN. PURPOSE—OBSERVE EVA, RMS OPERATIONS.	0.988

NOTES

(a) ITEMS (2), (5), (6), (7), AND (9) MAY ALSO ASSIST OBSERVATION OF TRA

(b) EVA SUIT WILL HAVE WORKLIGHTS.

(c) RUNNING LIGHTS AND BEACON FOR RENDEZVOUS NOT SHOWN.

(d) ALL LIGHTS AND TV CAMERAS SHOWN (EXCEPT OPEN CHERRY PICKER) ARE ALSO

Figure 6.4-2. Lights and TV Cameras for Con

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MERAS FOR CONSTRUCTION—SECOND MISSION

	PEAK POWER	ITEM NO.	DESCRIPTION—CHARACTERISTICS/USAGE	PEAK POWER
LE). NT,	0.180	(7)	TWO LAMP AND TV UNITS SIMILAR TO (5). LOCATION—SIDE OF BUILDING FIXTURE YOKE, FACING AFT END OF ETVP NEAR OUTER END. PURPOSE—OBSERVE EVA INSTALLATION OF THRUST STRUCTURE AND REMOVAL OF STRUTS FROM STOWAGE CANISTER ON ORBITER STARBOARD SIDE.	0.494
ILT	0.247	(8)	SIX METAL HALIDE LAMPS OF 0.200 kW EACH (STANDARD ITEMS). LOCATION—SIDE WALLS OF ORBITER PAYLOAD BAY (ONE OF SIX ILLUSTRATED). PURPOSE (FOR CONSTRUCTION)—BACKGROUND FOR EXTRACTING AND STOWING OF CONSTRUCTION EQUIPMENT. NOTE: SPECIAL DIFFUSERS OR BLINDS MAY BE NEEDED TO PROTECT TV CAMERAS FROM DIRECT VIEW OF LAMPS.	1.200
, P-	0.200	(9)	ONE TV CAMERA UNIT (STANDARD ORBITER ITEM) WITH TILT AND PAN MOUNT. LOCATION—AFT BULKHEAD OF ORBITER PAYLOAD BAY. PURPOSE (FOR CONSTRUCTION)—ASSIST IN GRAPPLING AND EXTRACTION OF MODULES AND CHERRY PICKER IN PAYLOAD BAY, TRANSPORT OF STRUTS.	0.047
	0.200	(10)	ONE TV CAMERA WITH TILT AND PAN MOUNT. LOCATION—RMS ELBOW (STANDARD ITEM). PURPOSE (FOR CONSTRUCTION)—ASSIST IN HANDLING BEAMS, OTHER MODULES IN SETUP, CONSTRUCTION, STOWAGE.	0.047
	0.247	(11)	ONE LAMP AND TV CAMERA FIXED TOGETHER ON TILT AND PAN MOUNT. LOCATION—RMS WRIST (STANDARD LOCATIONS, BUT NEW MOUNT) PURPOSE—ASSIST IN GRAPPLING MODULES, TRANSPORTING THEM, AND POSITIONING OR BERTHING THEM TO PERFORM SETUP, CONSTRUCTION, AND STOWAGE.	0.220
	0.988			

ERVATION OF TRANSLATION OF STRUCTURAL ASSEMBLY AND DEPLOYMENT OF LIBRATION DAMPER.

ICKER) ARE ALSO USED IN MISSION NO. 1.

mmeras for Construction—Second Mission

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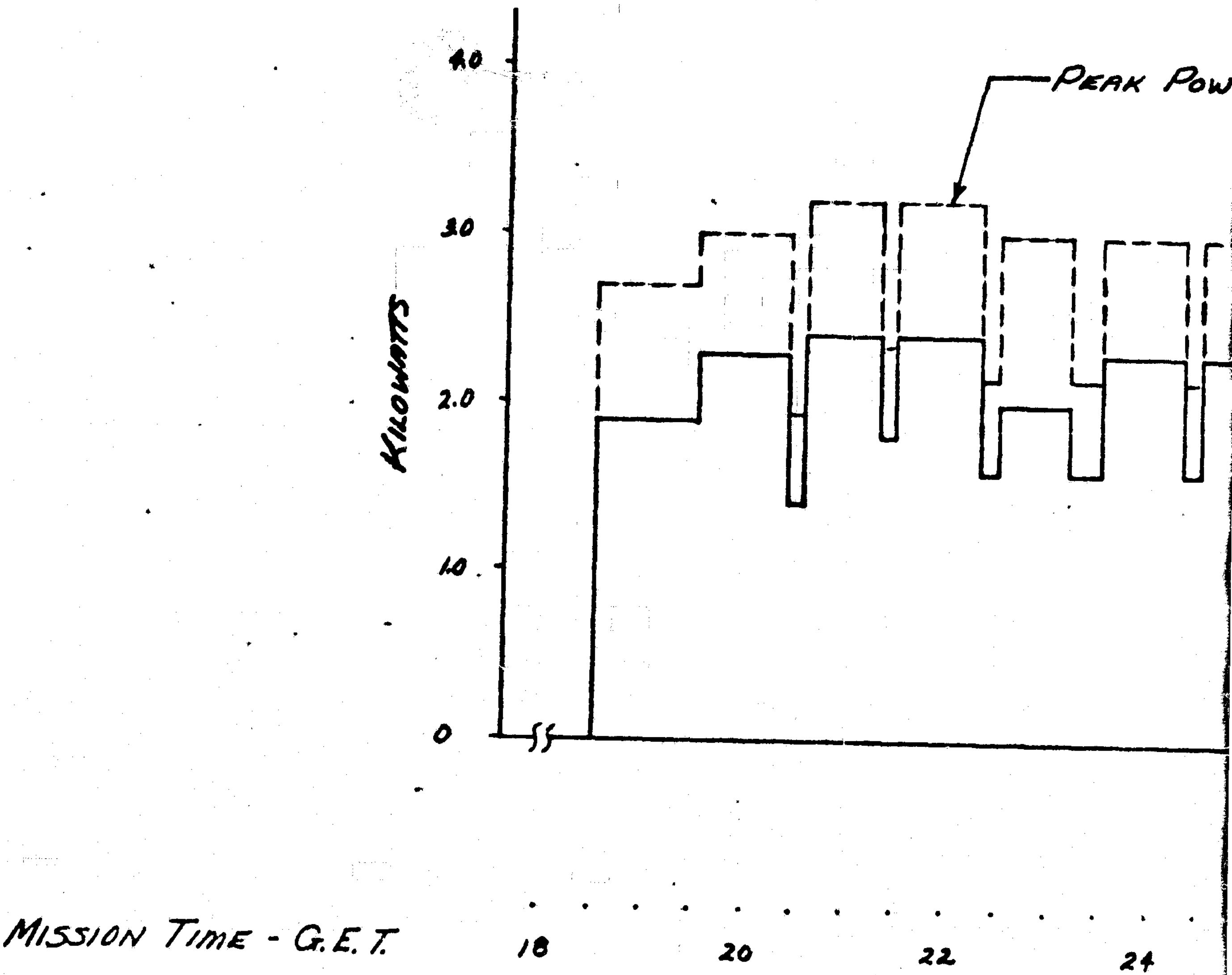

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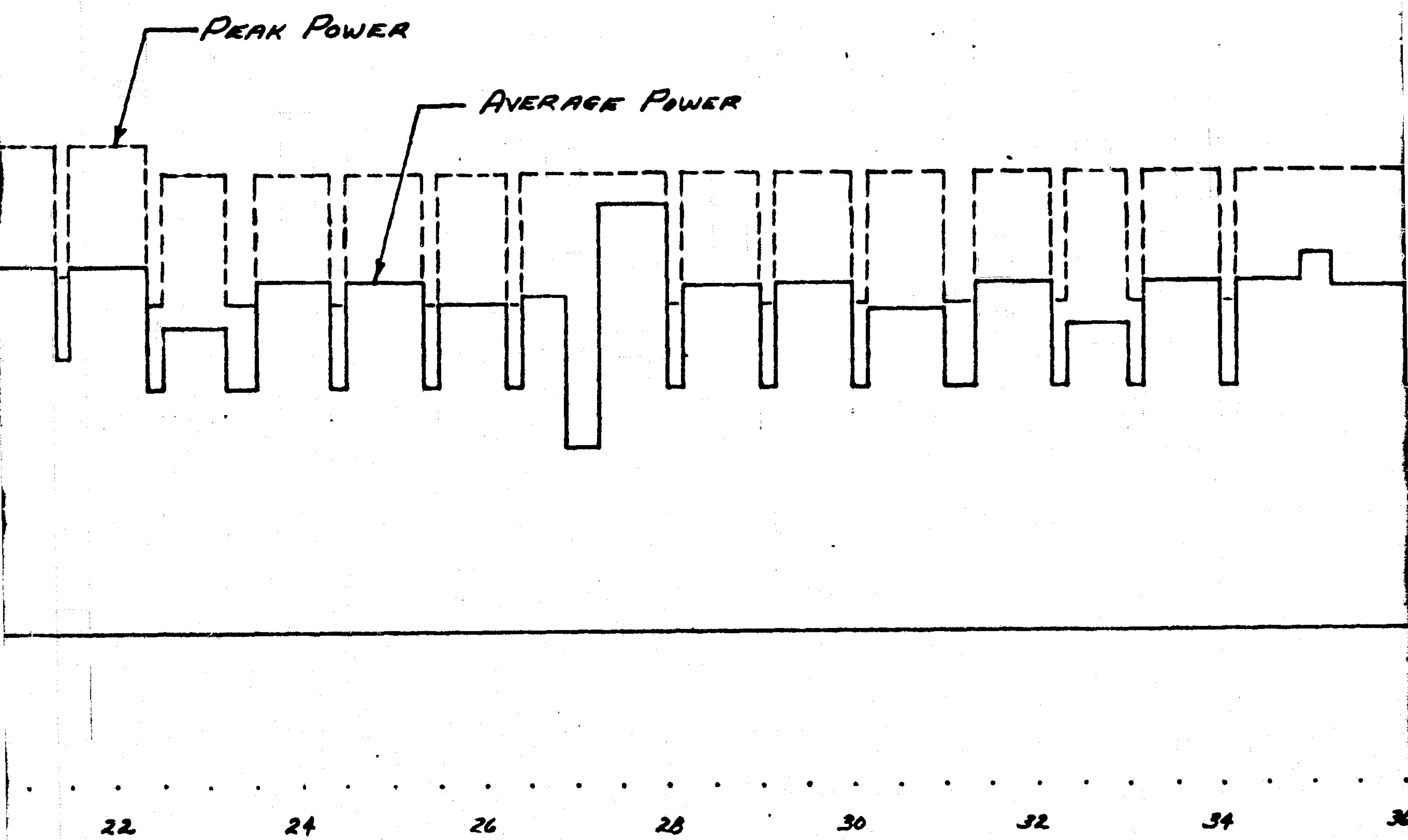

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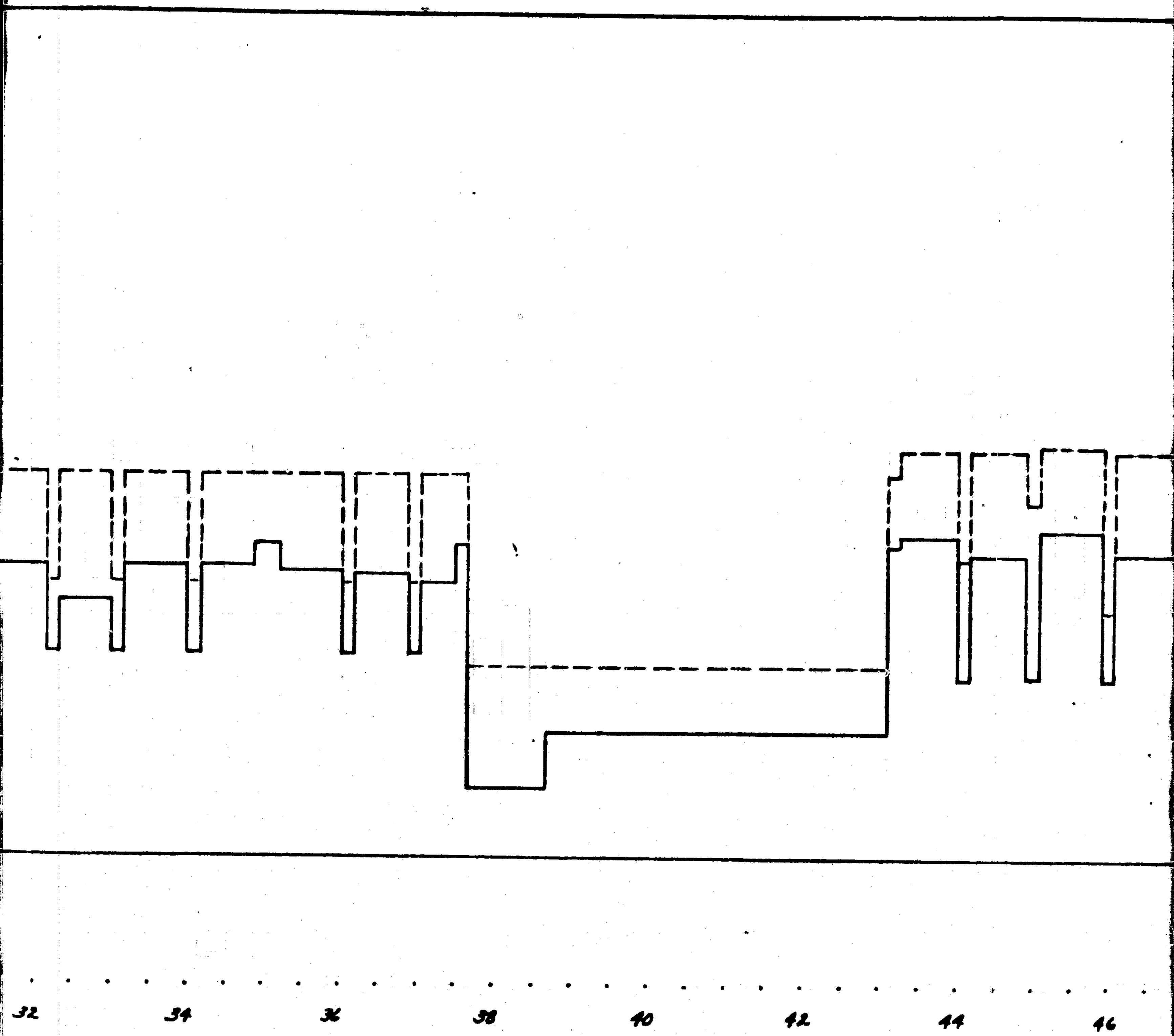

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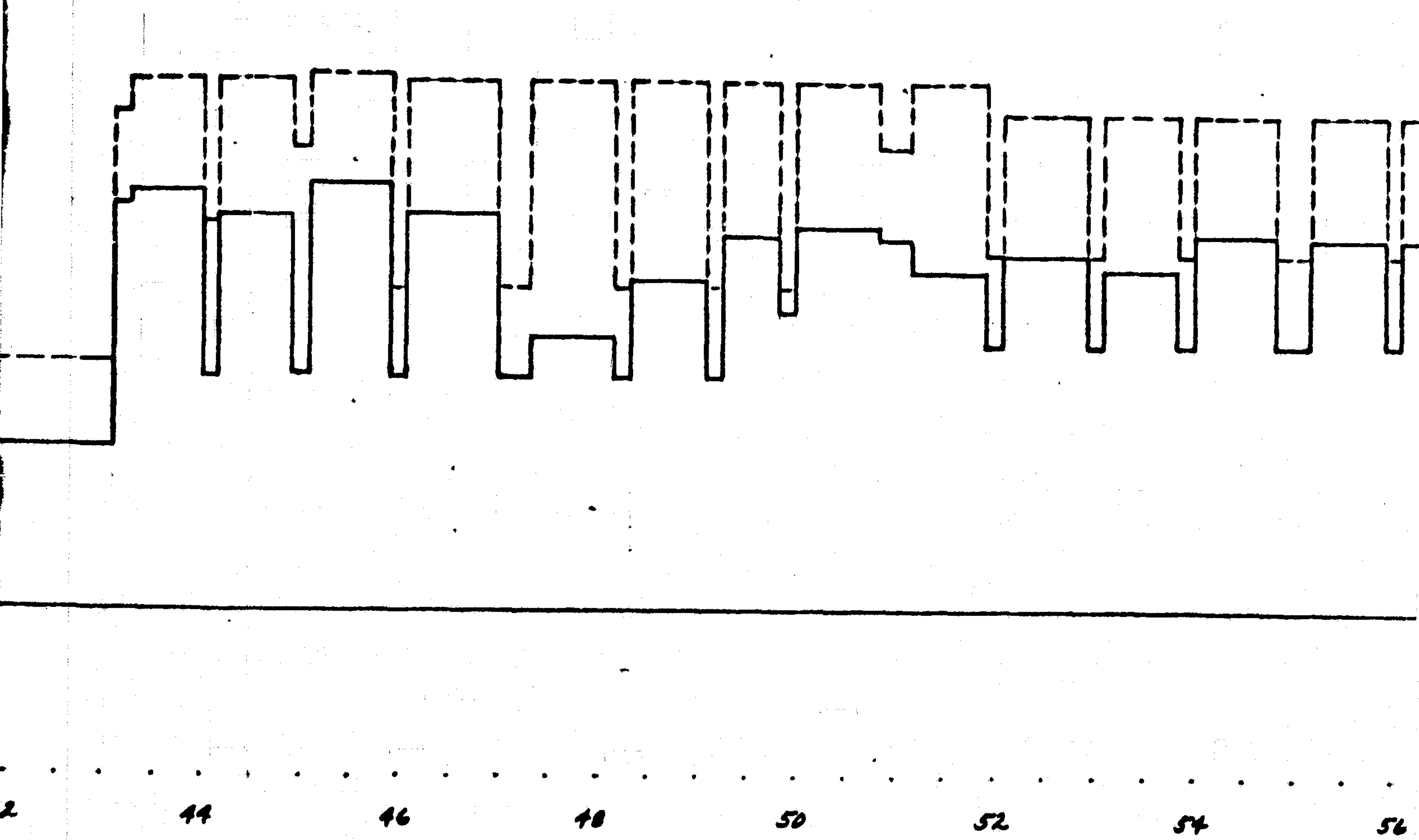

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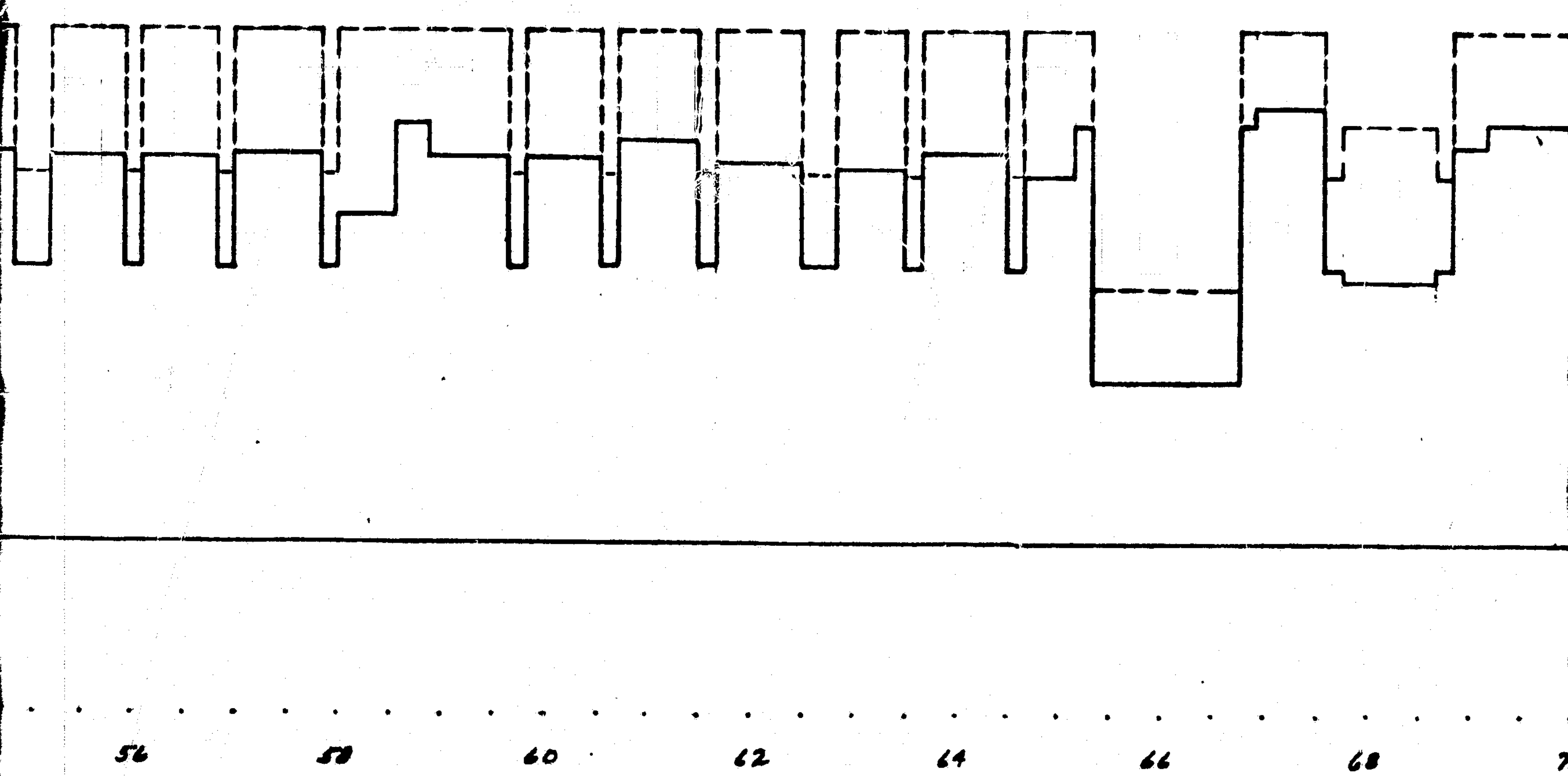
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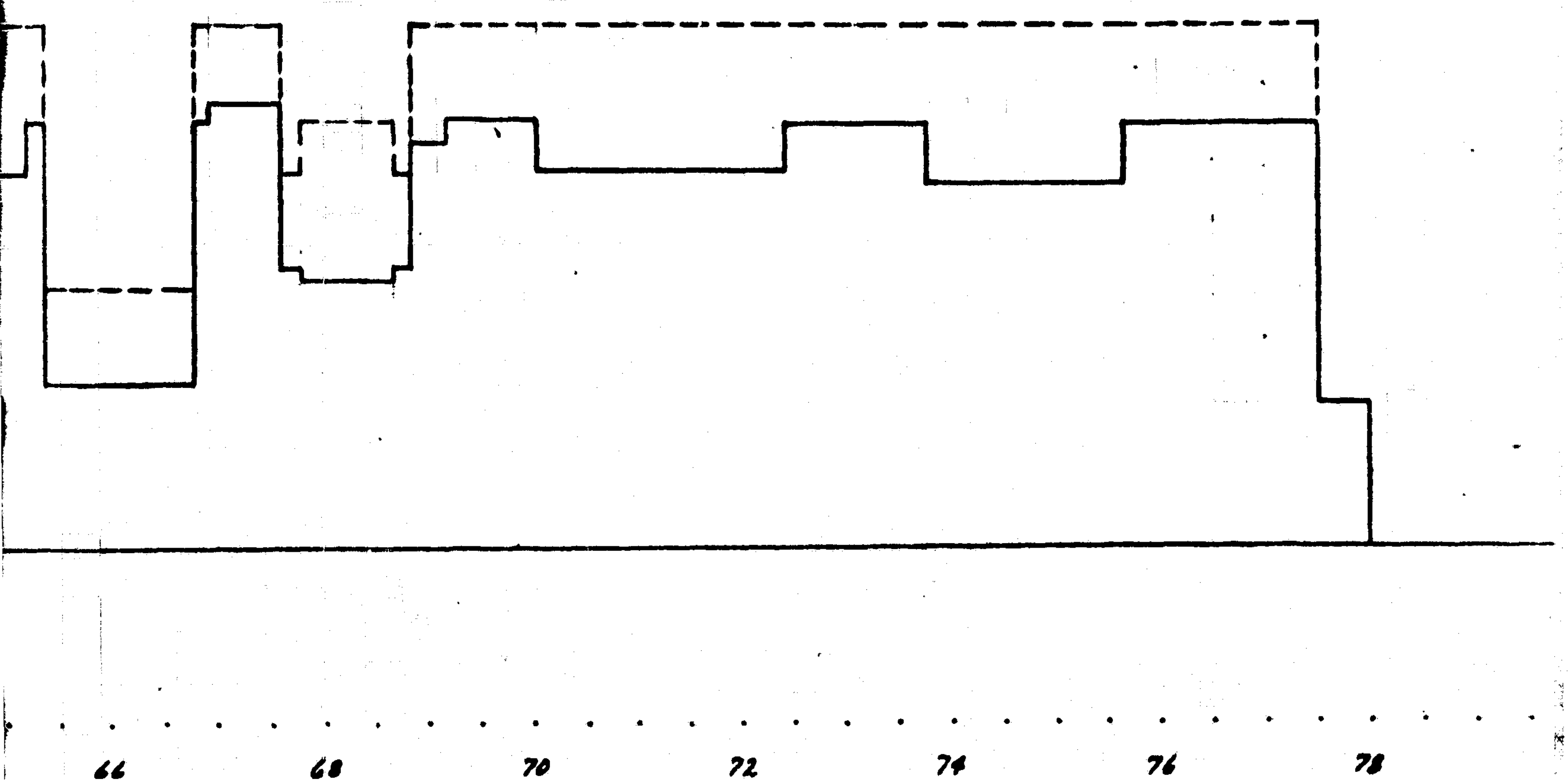

Figure 6.4-3. Power Profile—Second Mis

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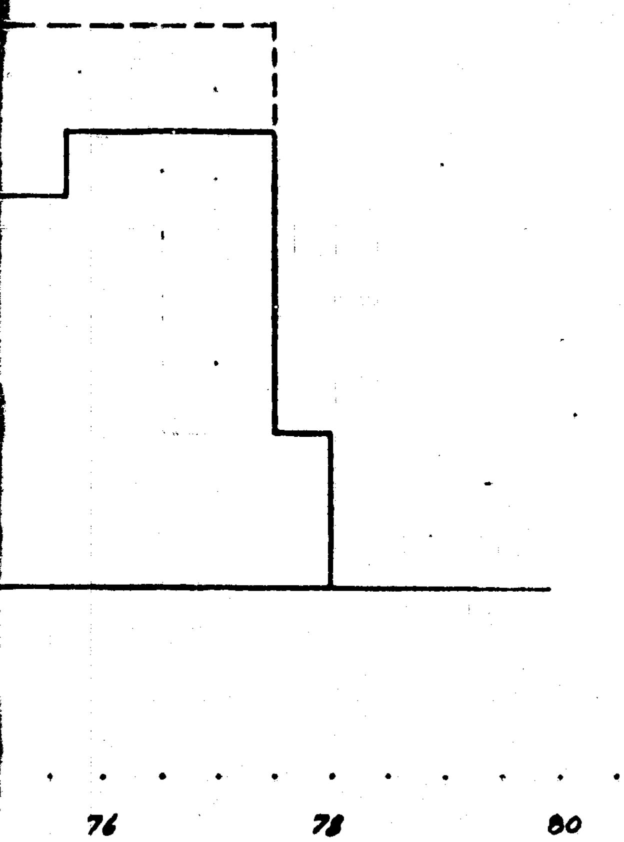

6.4-3. Power Profile—Second Mission

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Table 6.4-1 presents a summary of the power and energy requirements for the second mission. As for the first mission, the total energy demand still requires a cryogenic fuel supply kit in the orbiter to support the construction operations. However, the full potential energy capability of such a kit is never closely approached.

Table 6.4-1. Total Energy and Average Power - Second Mission

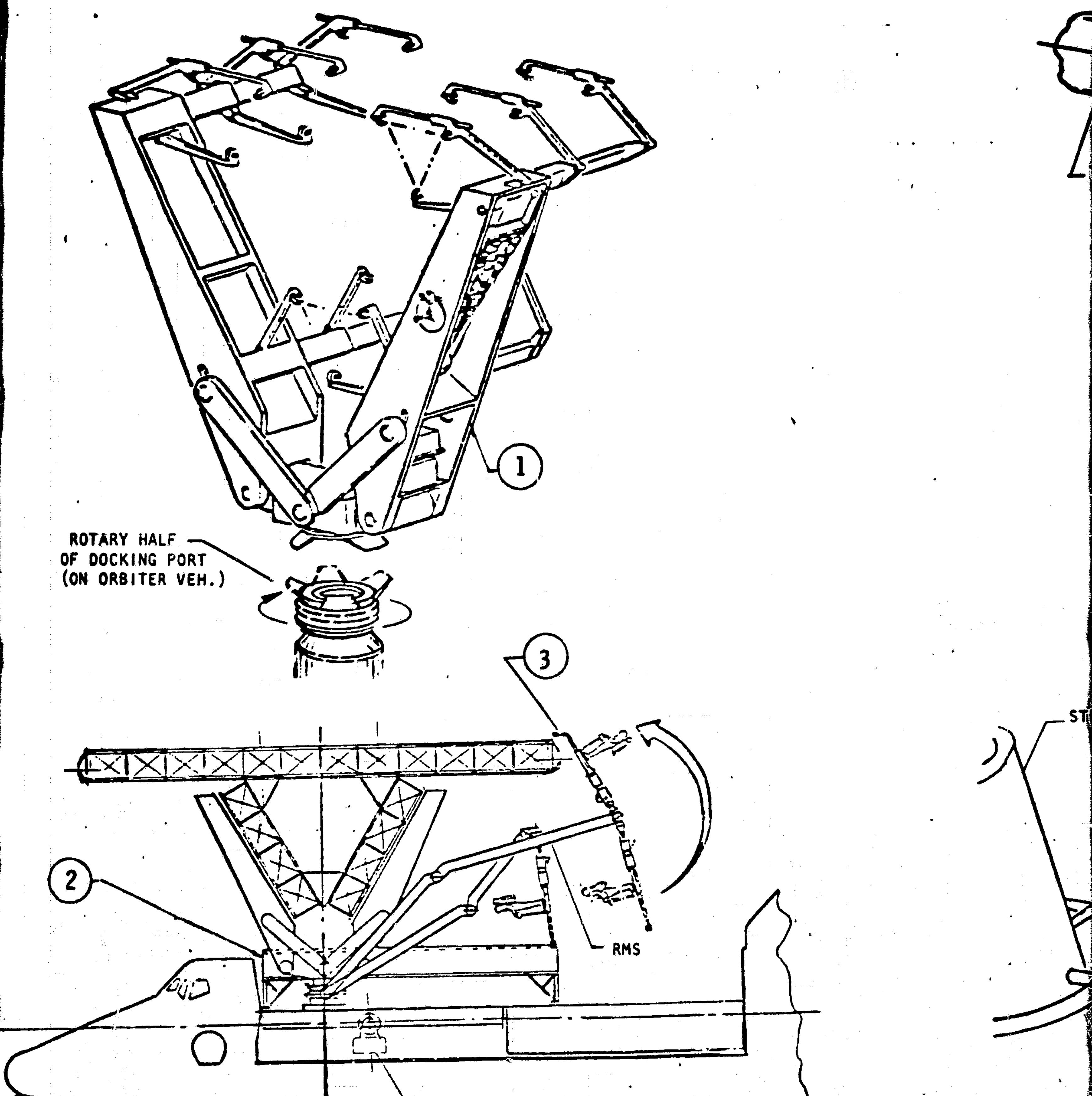
Activity Segment	Duration (Hr)	Energy Required (kWh)	Average Power (kW)
o Initial Activity - IVA	0.83	1.63	1.96
o EVA - Construction	50.12	98.91	1.97
o IVA - Alignment Measurements	8.00	17.06	2.13
o Shutdown Activity	0.50	.41	0.83
Nominal Total Energy	59.45	118.01	1.99
Design Margin (50% of Nominal)	27.3	53.78	1.97
Baseline Magnitudes for Construction Period	86.75 (3.61 days)	171.79	1.98

Lighting power requirements represent a larger percentage of power demand, about 45% for this mission as compared to about 33% for the first mission. Again, this reflects the reduced heating requirements for fabrication and assembly, rather than a greater usage of lamps.

6.4.5 Construction Support Equipment

During the second mission, use is continued for several basic elements of Construction Station No. 1. Since the central cross bridge structure was removed, the platform can be translated through it in either direction. However, removal of the EVA work station requires new provisions for EVA support. These are provided by a different version of the basic open cherry picker, which is attached to the RMS. The cherry picker is now fitted with a powered maneuverable handling boom and special end effector suitable for handling both modules and struts. To minimize requirements for end effector types, the design of modules must incorporate a grapple fixture which will mate with this new end effector.

Construction support equipment for the second mission is described in Figure 6.4-4.



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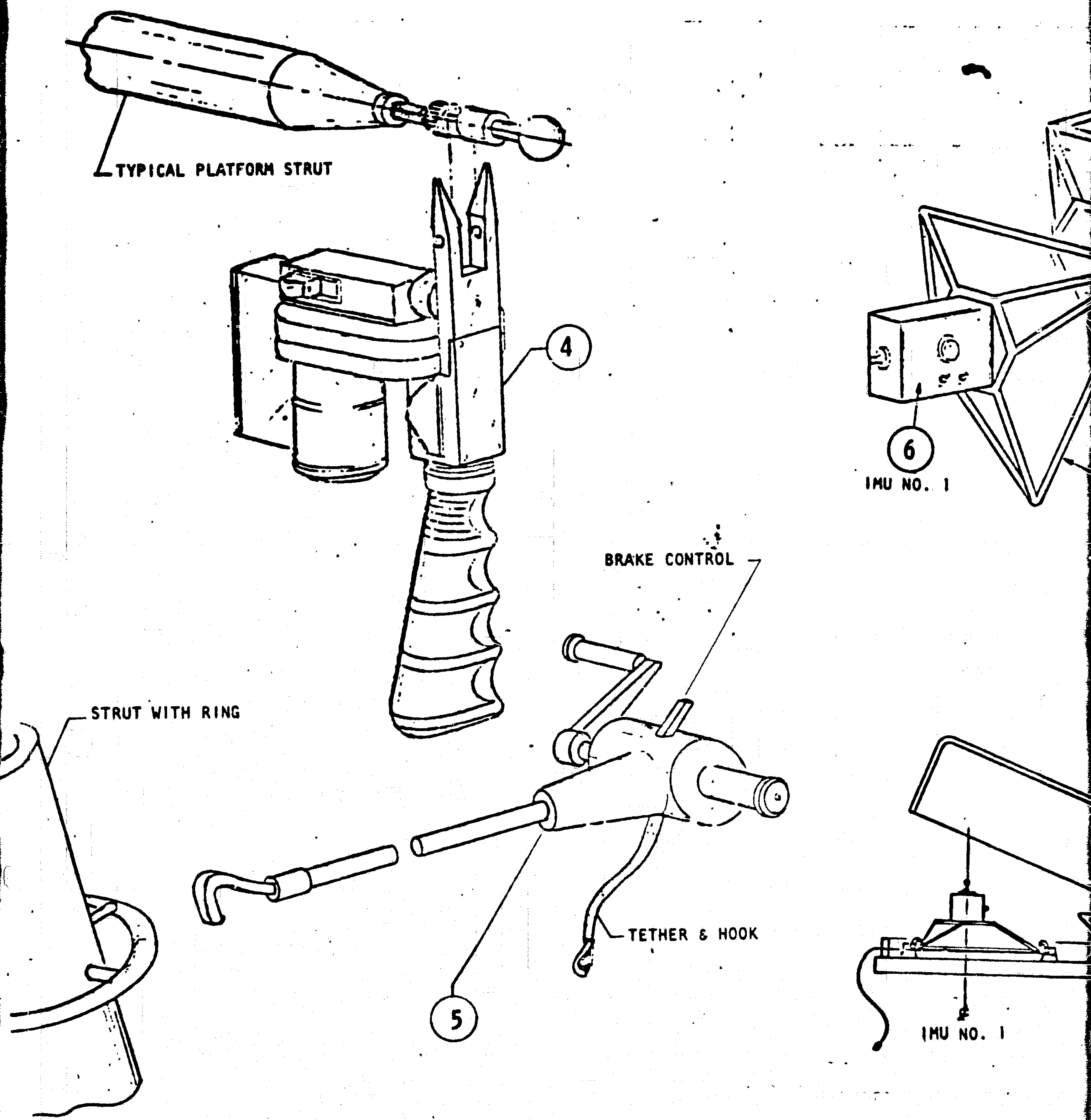

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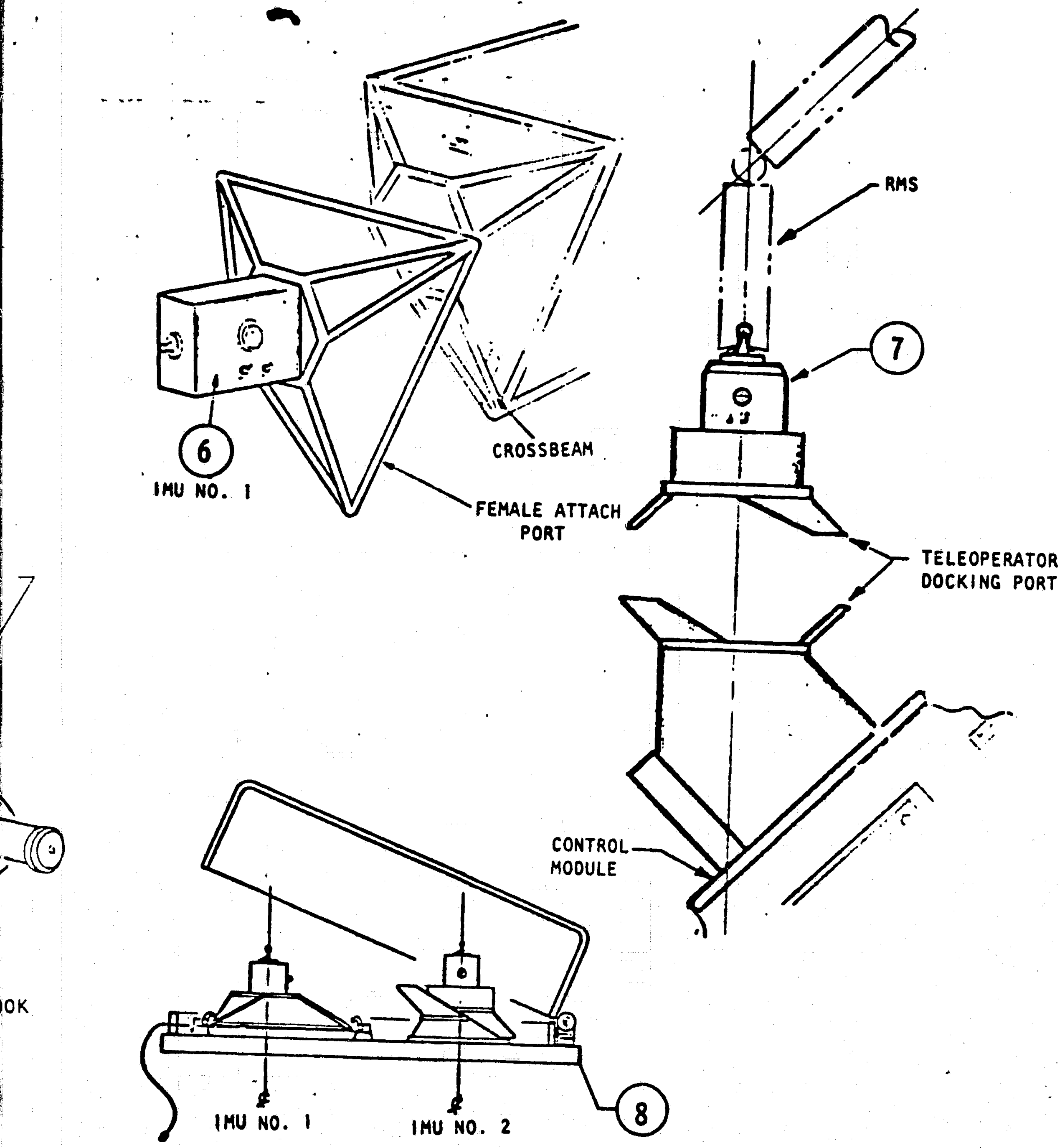

I.D.
1
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6 7
8
9

TELEOPERATOR
DOCKING PORT

I.D.	DESCRIPTION
(1)	BUILDING FIXTURE ASSEMBLY. THIS FIXTURE ASSEMBLY IS THE SAME PIECE OF EQUIPM TECHNOLOGY VERIFICATION PLATFORM (ETVP), BUT WITH THE BRIDGE BEAM AND ASSOCIA OF PLATFORM ASSEMBLY, ONLY THE STRUCTURAL YOKE AND THE BEAM SUPPORT ARM ASSEM
(2)	STRUT CONTAINER. A STRUT CONTAINER MODULE IS UTILIZED FOR STORING AND SUPPOR ETVP. THE CONTAINER IS LOCATED AT THE FORWARD END OF THE ORBITER BAY, ON THE IS ROTATED OUT OF THE BAY FOR EASY ACCESS TO ITS CONTENTS BY THE RMS WITH THE
(3)	CHERRY PICKER AND HANDLING BOOM. IN THE SECOND MISSION, THE CHERRY PICKER WI WITH THIS TOOL AND AN ASTRONAUT SUPPORTED ON THE EVA WORK PLATFORM, STRUTS AR PLATFORM FOR ATTACHMENT.
(4)	STRUT LENGTH ADJUSTING TOOL. THIS IS A MANUALLY OPERATED TOOL FOR ADJUSTING THE PLATFORM ASSEMBLY. SINCE THIS TOOL IS PORTABLE DURING ITS WORK CYCLE, PR WHEN NOT IN ACTUAL USE.
(5)	HAND-CRANKED STEM DEVICE. THIS DEVICE EXTENDS THE REACH OF THE ASTRONAUT FOR WHICH CAN BE STOWED ON A ROLLER WITHIN THE DEVICE BY USE OF THE CRANK.
(6)(7)	IMU NO. 1 & IMU NO. 2. IMU NO. 1, SHOWN MOUNTED ONTO THE ATTACH FITTING, WIL IN THREE ORTHOGONAL AXES, PLUS PROVIDE A TIMELINE AS TO WHEN DATA WERE TAKEN. PORTS, RCS MODULE ATTACH PORTS AND ALL THE PROPULSION MODULE ATTACH FITTINGS, IDENTICAL IN ITS REQUIRED PERFORMANCE TO IMU NO. 1. HOWEVER, IMU NO. 2 IS MO SYSTEM WILL BE USED TO MEASURE AND RECORD THE RELATIVE ORIENTATION BETWEEN TH ON THE CM.
(8)	BASELINE MOUNTING FIXTURE. THE BASELINE MOUNTING FIXTURE PROVIDES A PLATFORM ORBITER. THE BASE ALSO PROVIDES A FACILITY TO CALIBRATE AND COMPARE BOTH IMU COVER PROVIDES A RIGID STABLE BASE TO PROTECT BOTH IMU UNITS FROM STRUCTURAL
(9)	CHECKOUT SYSTEM. THIS MODULE IS USED TO VERIFY THE SCM OPERATIONS AND ELECTR

Figure 6.4-4. Construction Support E

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DESCRIPTION
TURE ASSEMBLY IS THE SAME PIECE OF EQUIPMENT USED DURING CONSTRUCTION OF THE INITIAL ENGINEERING AND (P), BUT WITH THE BRIDGE BEAM AND ASSOCIATED FABRICATION ELEMENTS REMOVED. DURING THIS SECOND PHASE TURAL YOKE AND THE BEAM SUPPORT ARM ASSEMBLIES ARE REQUIRED.
MODULE IS UTILIZED FOR STORING AND SUPPORTING ALL THE BRACING STRUTS REQUIRED FOR INSTALLATION ON THE HE FORWARD END OF THE ORBITER BAY, ON THE STARBOARD SIDE. DURING ACTUAL USE, THE CONTAINER WITH STRUTS CCESS TO ITS CONTENTS BY THE RMS WITH THE CHERRY PICKER.
THE SECOND MISSION, THE CHERRY PICKER WITH A STRUT HANDLING BOOM IS SUPPORTED ON THE END OF THE RMS. ORTED ON THE EVA WORK PLATFORM, STRUTS ARE REMOVED FROM THE STRUT CONTAINER AND TRANSPORTED TO THE
A MANUALLY OPERATED TOOL FOR ADJUSTING THE LENGTH OF THE STRUT AFTER ONE END HAS BEEN ATTACHED INTO OOL IS PORTABLE DURING ITS WORK CYCLE, PROVISIONS ARE BUILT ONTO THE CHERRY PICKER TO SECURE THE TOOL
E EXTENDS THE REACH OF THE ASTRONAUT FOR HANDLING STRUTS. THE POLE PORTION IS FORMED AS A THIN SHEET N THE DEVICE BY USE OF THE CRANK.
OWN MOUNTED ONTO THE ATTACH FITTING, WILL BE UTILIZED TO MEASURE AND CONTINUOUSLY RECORD ORIENTATION DE A TIMELINE AS TO WHEN DATA WERE TAKEN. THIS PIECE OF EQUIPMENT WILL BE USED TO MEASURE ALL PAYLOAD LL THE PROPULSION MODULE ATTACH FITTINGS, TO DETERMINE ALIGNMENT RELATIVE TO IMU NO. 2. IMU NO. 2 IS TO IMU NO. 1. HOWEVER, IMU NO. 2 IS MOUNTED ONTO A FEMALE TELEOPERATOR DOCKING PORT AS SHOWN. THIS CORD THE RELATIVE ORIENTATION BETWEEN THE SYSTEM CONTROL G&N BASE AND THE TELEOPERATOR PORTS MOUNTED
LINE MOUNTING FIXTURE PROVIDES A PLATFORM TO TRANSPORT BOTH IMU NO. 1 AND IMU NO. 2 WHILE IN THE CILITY TO CALIBRATE AND COMPARE BOTH IMU UNITS BEFORE AND AFTER USE. THIS FIXTURE PLATFORM AND PROTECT BOTH IMU UNITS FROM STRUCTURAL OR THERMAL DISTORTION WHEN NOT IN ACTUAL USE.
TO VERIFY THE SCM OPERATIONS AND ELECTRICAL CONTINUITY OF THE ETVP.

Figure 6.4-4. Construction Support Equipment for Second Mission

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6.4.6 Flight and Site Support Equipment

General comments in Section 5.4.6 also apply herein. Unique requirements for the second mission include a stowage pallet for the open cherry picker, the checkout unit, the alignment measuring IMU storage unit, the forward assembly modules and the forward and aft deployable support structures. At the end of Mission 2, the libration damping system on the construction fixture is again employed for unattended flight stabilization.

6.5 CARGO MANIFEST

Table 6.5-1 summarizes the cargo types and weights for the second construction mission. Details are presented in Appendix C.

Table 6.5-1. Cargo Manifest Weight Summary

Launch Mode	Weight (lb)	Mass (kg)
Platform Items (Satellite)	23,660	10,732
Construction Items	990	449
Airborne Support Equipment	8,957	4,063
Total Cargo (Up)	33,607	15,244
Return Mode		
Construction Items	990	449
Airborne Support Equipment	8,957	4,063
Less Expendables	-1,033	-469
Total Cargo (Return)	8,914	4,043

The following assumptions were made with respect to developing the cargo mass statement.

1. Mission based on six crewmen for six days. This 36 man days is an increase of 8 man days over the orbiter baseline of 28 man days. Thus, an additional 8 man days of crew systems is provided.

2. Eight additional airlock repressurizations. A total of 10 is required (two are orbiter baseline). Each nitrogen tank kit has a capacity of 4.5 EVA's. Thus, two additional N_2 tank kits are required (Kits Nos. 5 and 6). The oxygen required for repressurizing the airlock is 2.7 lb. Thus, 21.6 lbs for the eight additional repressurizations. The additional cryokit (see next item) provides an excess of 56 lbs of oxygen that can be used for this loss.

3. Eight man days of additional metabolic oxygen at 2.08 lb/man day, or 16.6 lbs, combined with the airlock loss gives 37.2 lbs which results in an 18.8 lb remaining reserve in the cryo O_2 kit.

4. [illegible] t No. 3 has been added over the Orbiter 2 kit baseline. In addit on to supplying electrical power, it has the benefit of supplying oxygen for the airlock loss and crew metabolic requirements.

5. Fixed life support items added for two additional crewmen.

6. All cryo expanded (as water) overboard for return. Forty pounds per tank of N_2 gas expended overboard for return.

7. Additional 8 man day of crew water (93 lbs) supplied by water produced from the additional cryokit.

Figure 6.5-1 shows the cargo horizontal c.g. plotted on the orbiter c.g. envelope constraints for both the up, or abort condition, and for return case. As will be noted, both cases are satisfactory from a c.g. standpoint. Also, the lateral and vertical c.g.'s are well within the orbiter c.g. envelope. The mass of the total cargo is 15,241 kg (33,607 lbs). The normal return mass is 4,043 kg (8,914 lbs).

Figure 6.5-2 illustrates the orbiter packaging arrangement for the ascent phase. Further details are shown in Drawing No. 42662-67 in Appendix A.

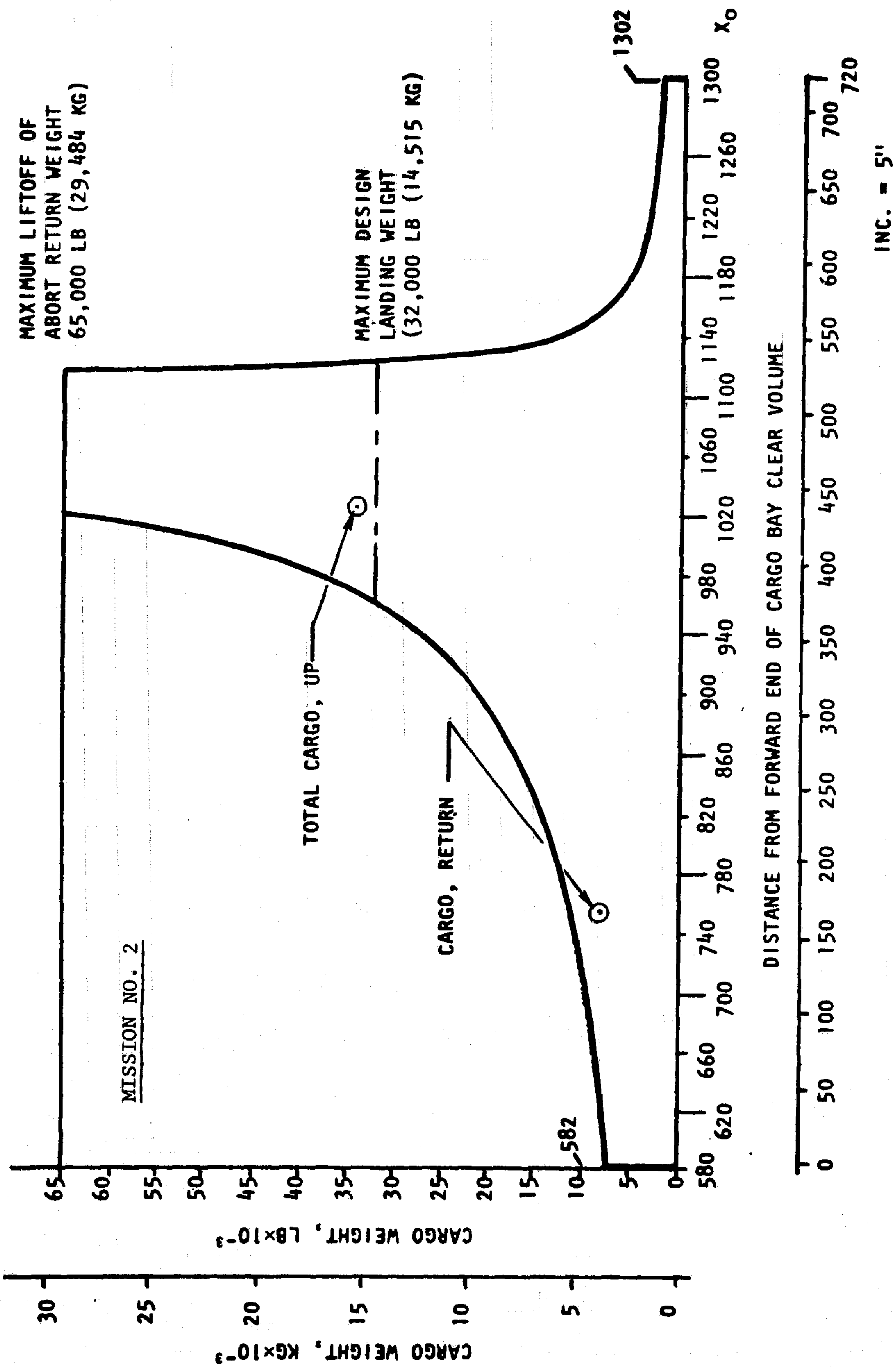

Figure 6.5-1. Cargo Center-of-Gravity Locations

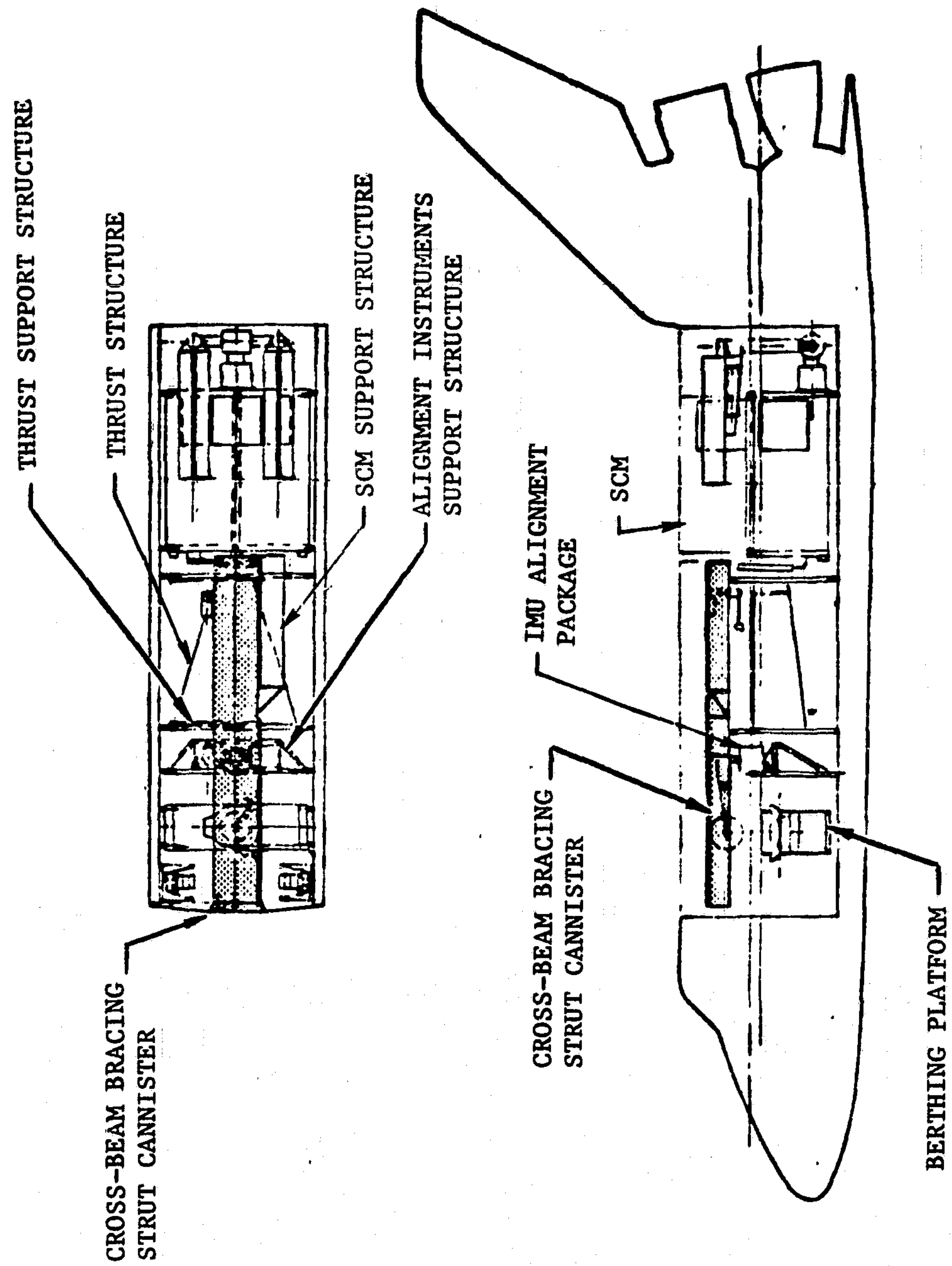

Figure 6.5-2. Second Mission Mainfest

7.0 THIRD CONSTRUCTION MISSION

This section describes the detailed integration of the activities for the third construction mission.

7.1 CONSTRUCTION PLAN

The objective of the third mission plan was to complete the construction of the platform and activate it to begin operations in low earth orbit (LEO). This scenario concept delays installation of the three orbital propulsion modules until near the end of the operations period at LEO.

A secondary mission objective (not analyzed) could be the installation of payload modules, since it was found that considerable volume is available in the orbiter payload bay beyond that required to accomplish the primary objectives.

Completion of the platform construction requires installation of four reaction control system (RCS) pods, one on each end of the extreme forward and aft crossbeams. The resulting configuration is shown in Figure 7.1-1. Note that the construction fixture is left on the operational platform spacecraft in a passive state as an aid to later servicing, payload installation, and payload changeout or modifications during operations in low earth orbit. (The construction fixture is removed prior to transfer to GEO.)

7.1.1 Construction Requirements

Construction requirements specific to the third mission are listed in Table 7.1-1.

7.1 2. Construction Logic

The logic diagram for the third mission is presented in Figure 7.1-2.

7.2 CONSTRUCTION PROCESS

The construction process in the third mission is preceded by a rendezvous and berthing operation similar to that for the second mission. Also, as in Mission 2, initial construction preparations include stowage of libration damper RCS pods and attaching an open cherry picker to the end of the RMS, followed by unfolding of the cherry picker and boarding by an EVA astronaut.

The first actual construction operations involve the cherry picker grappling an RCS pod stowed in the aft end of the orbiter payload bay and installing it at the end of the forward crossbeam attach port. To assure both adequate clearances and adequate reach, the platform may have to be translated a short distance through the construction fixture. The installation operation is repeated for a second RCS pod at the opposite end of the crossbeam as shown in Figure 7.2-1.

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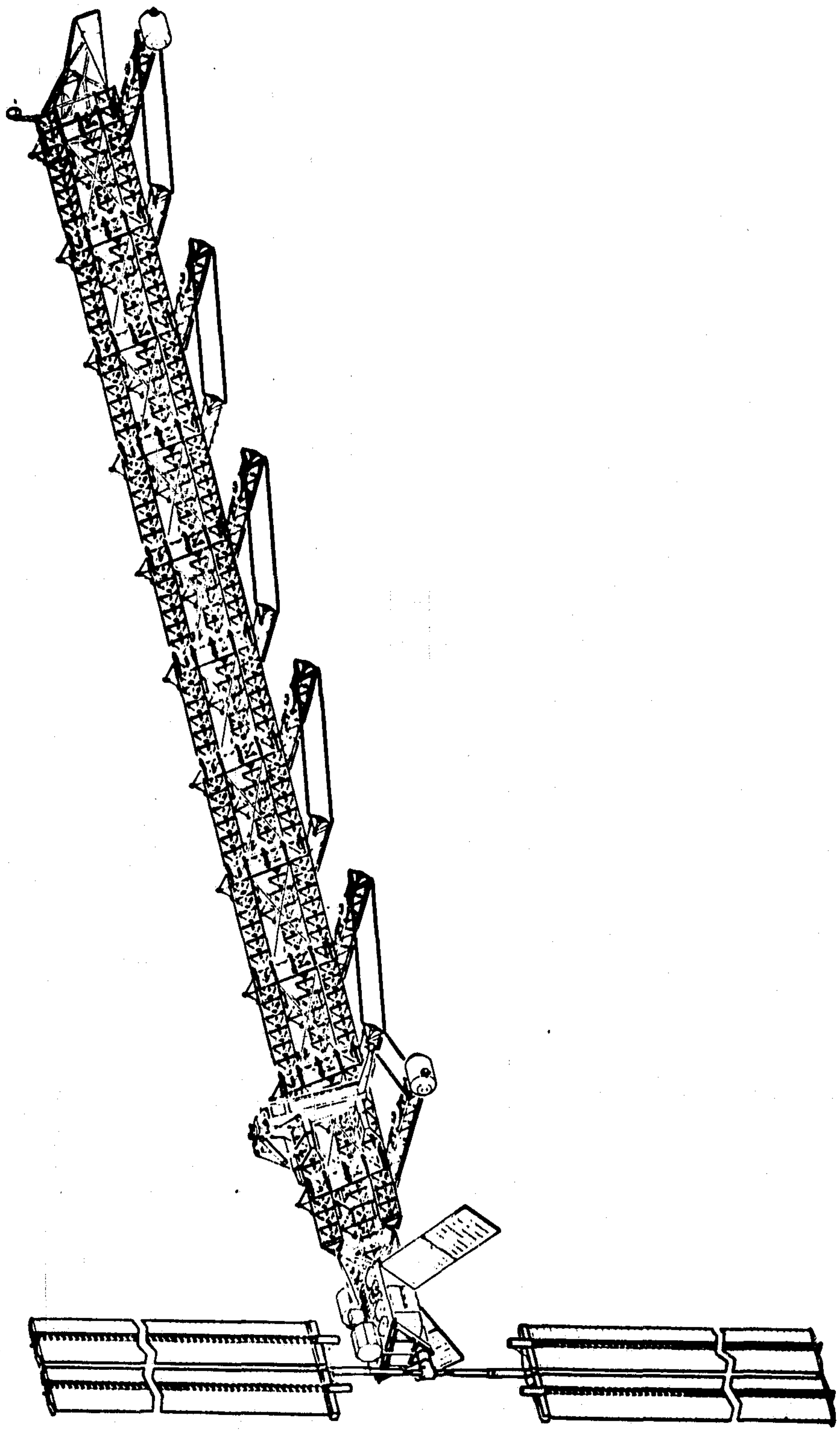
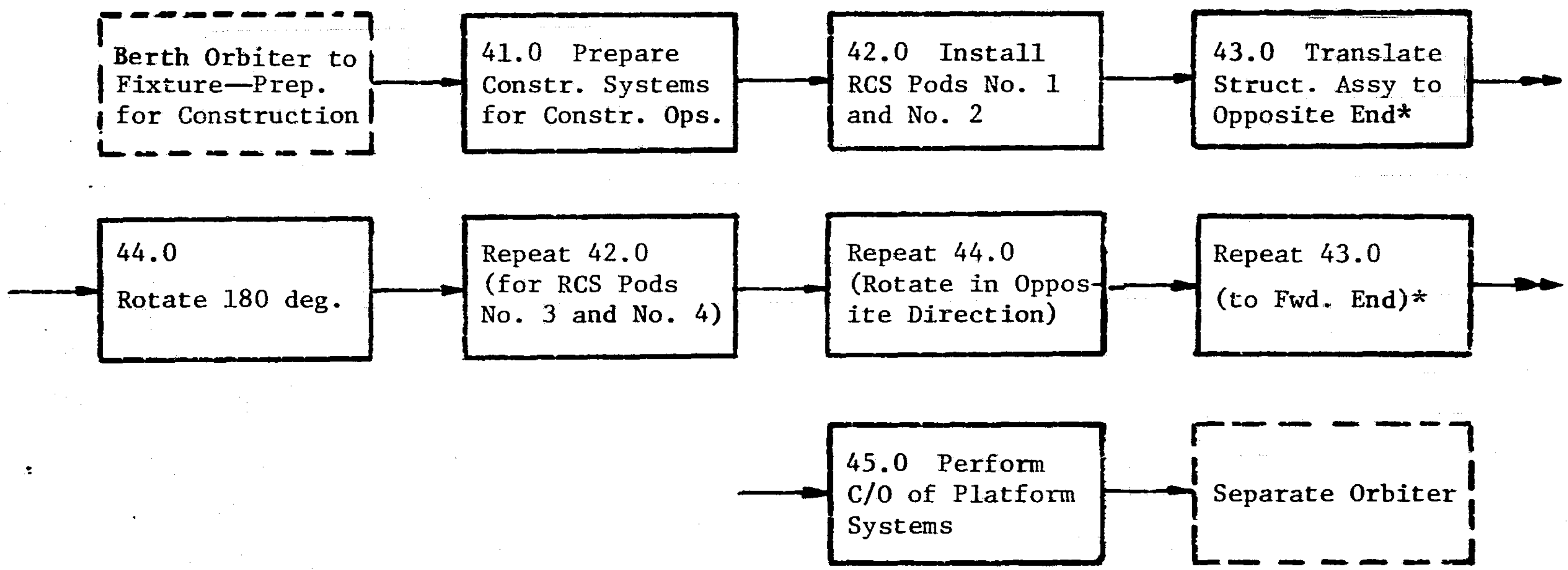


Figure 7.1-1. ETVP Configuration at Completion of Third Mission

Table 7.1-1. Construction Requirements for the Third Mission

• PROVIDE FOR INSTALLATION OF FOUR RCS PODS.
• PROVIDE FOR MEANS TO ACTIVATE AND CHECK OUT ALL SYSTEMS ON THE ENTIRE PLATFORM TO ASSURE OPERATIONAL READINESS FOR LOW EARTH ORBIT (LEO) OPERATIONS.
• PROVIDE MEANS TO RENDEZVOUS AND SAFELY BERTH WITH THE ORBITING CONSTRUCTION FIXTURE/PLATFORM ASSEMBLY PRIOR TO BEGINNING CONSTRUCTION OPERATIONS.
• PROVIDE MEANS FOR REVISIT TO THE ORBITING PLATFORM SPACECRAFT FOR CHANGEOUT OR INSTALLATION OF PAYLOADS, FOR SERVICING OF PLATFORM SYSTEMS, AND FOR UPDATING/REFURBISHING PRIOR TO TRANSFER OF THE PLATFORM TO GEOSYNCHRONOUS ORBIT.
• PROVIDE MEANS FOR SAFE SEPARATION OF THE ORBITER FROM THE ACTIVATED PLATFORM.



*Payloads may be installed in parallel with this activity.

Figure 7.1-2. Logic Diagram for Construction Activities during Third Mission

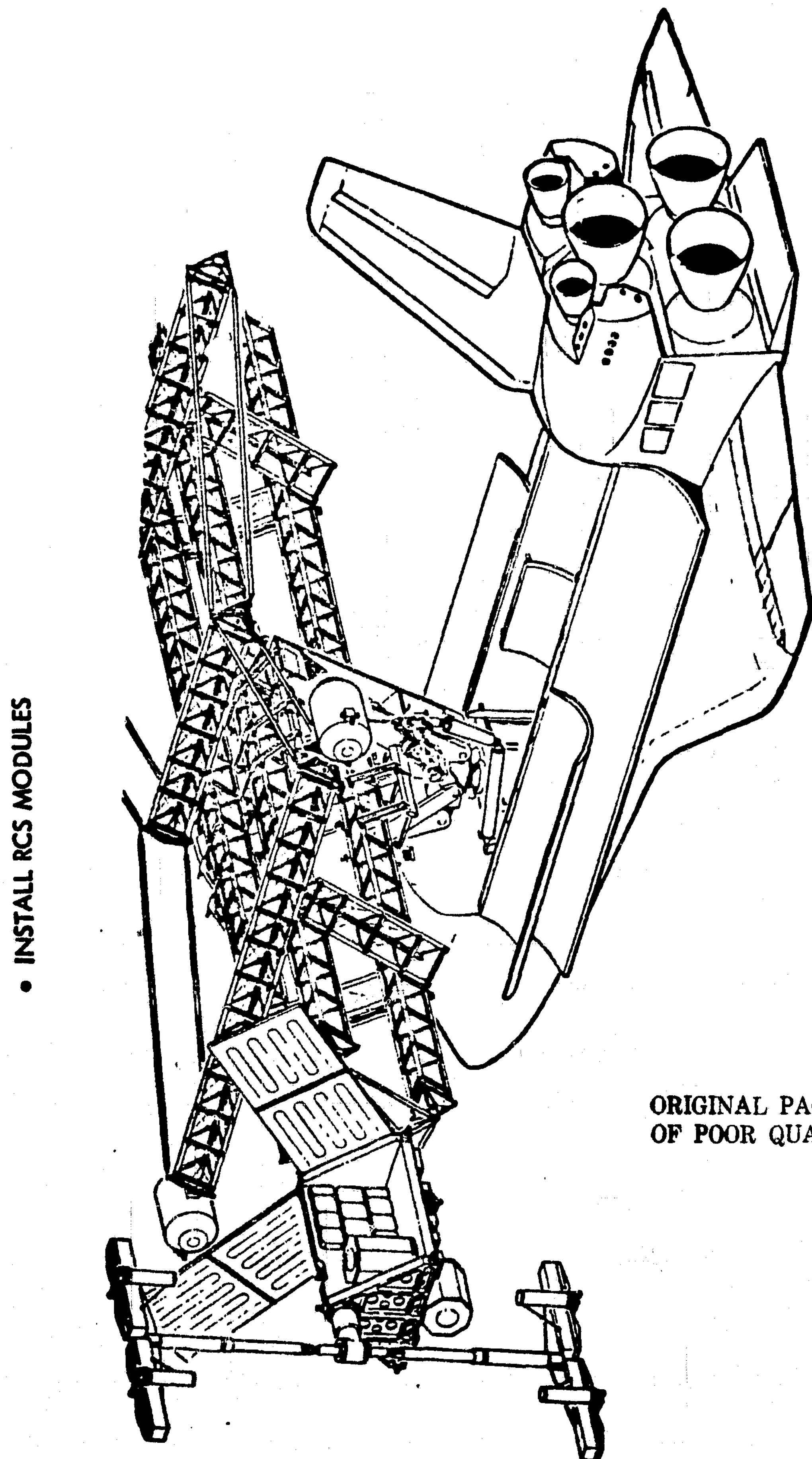


Figure 7.2-1. Installation of RCS Modules

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The use of a cherry picker for this module installation operation was based on the following considerations. First, the pod is a large module, awkward to handle and align to the attach ports by using the RMS alone. The reach would be difficult. However, such considerations alone would not necessarily preclude use of the RMS. The second consideration was that the following major activity would be a checkout procedure in which the presence of the EVA astronaut could be useful in case of anomalies in measurements or hangups in operations. A third consideration is that the cherry picker provides a useful extension of reach for the RMS arm, facilitating the function of pulling an electrical umbilical cable from the orbiter to the forward assembly in order to activate the platform systems and perform final checkout. The connection site is one of the teleoperator docking ports which is fitted with a special connector. The checkout umbilical has an end fitting which mates mechanically with the teleoperator port prior to making the electrical connection.

The checkout activity includes full deployment of the solar array and test of the RF command and control links. Following checkout, the electrical umbilical cable is removed and returned to the orbiter by the EVA astronaut on the cherry picker as shown in Figure 7.2-2.

Figure 7.2-3 summarizes the major translations and rotations of the platform with respect to the orbiter during the third mission. Using the same convention as in Figure 6.2-7, the platform is portrayed as stationary, while the orbiter is shown as translating and rotating. In contrast to motions in the third mission, the orbiter reverses its direction of rotation and retraces its path, to the position and orientation it had upon berthing at the beginning of the mission. The RMS and cherry picker is, thus, in a favorable orientation to attach an electrical umbilical cable to the system control module to enable platform activation and final checkout.

7.3 CONSTRUCTION ACTIVITY ANALYSES

The nature of activity in the third mission is similar to that in the second, except that it is shorter and has no parallel operations. There are only two significant types of construction activities—that of installing the four RCS pods and that of performing the final activation and checkout of the platform. The other activities are actually repositioning motions which facilitate the installation and checkout. As in the second mission, there are rotations of the platform with respect to the orbiter about the berthing port axis. These are similar, but occur in opposite directions. The installation of RCS pods and the checkout operations are somewhat repetitious activities, but all tasks and movements are accounted for in the descriptions.

The Construction Activity Data Sheets for Mission 3 appear in Appendix B as numbers 41.0 through 45.0. As in the case of the previous mission analyses, the function of separation of the orbiter from the construction fixture is not described as a construction activity.

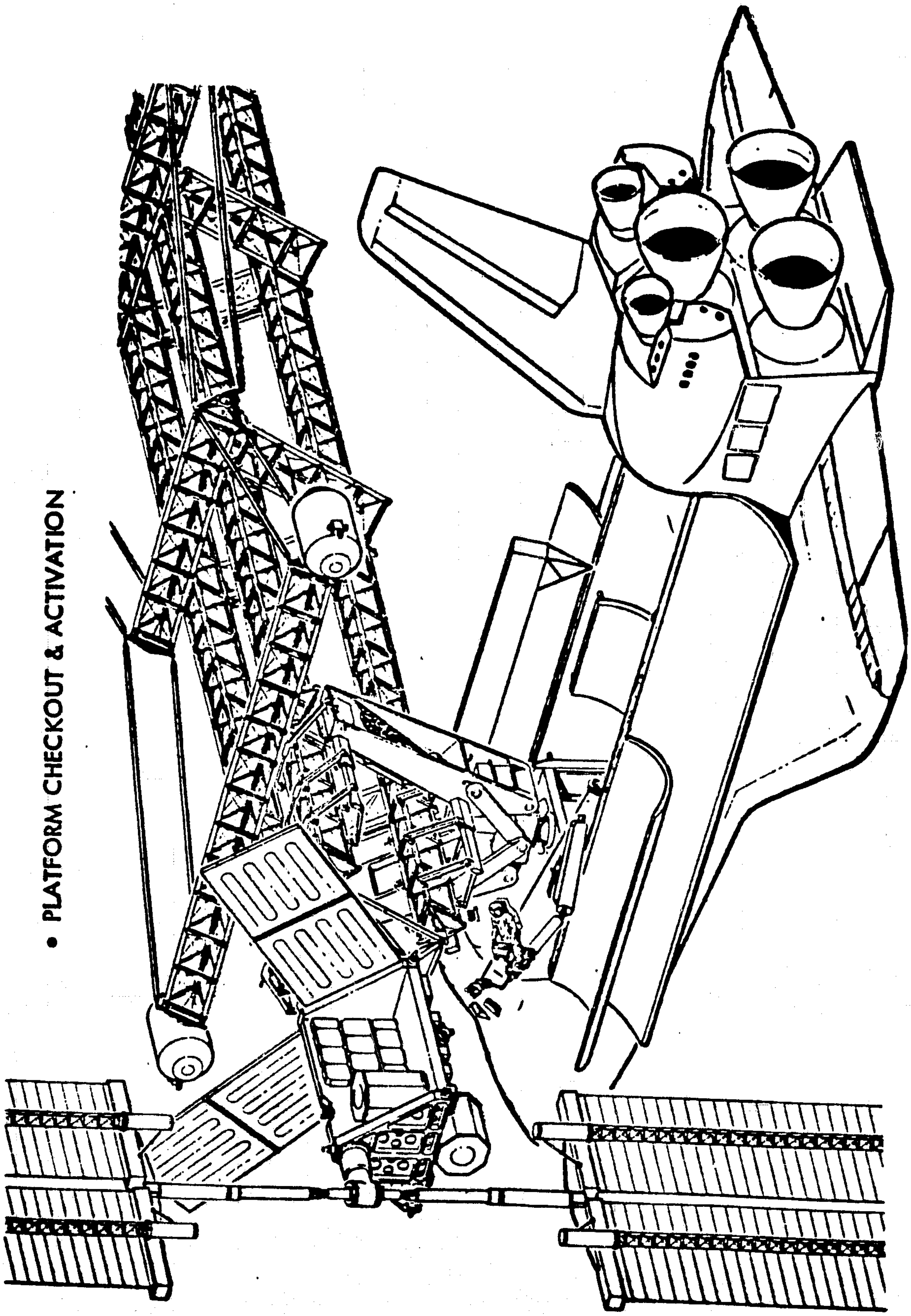

Figure 7.2-2. Removal of Umbilical Following Platform Checkout and Activation

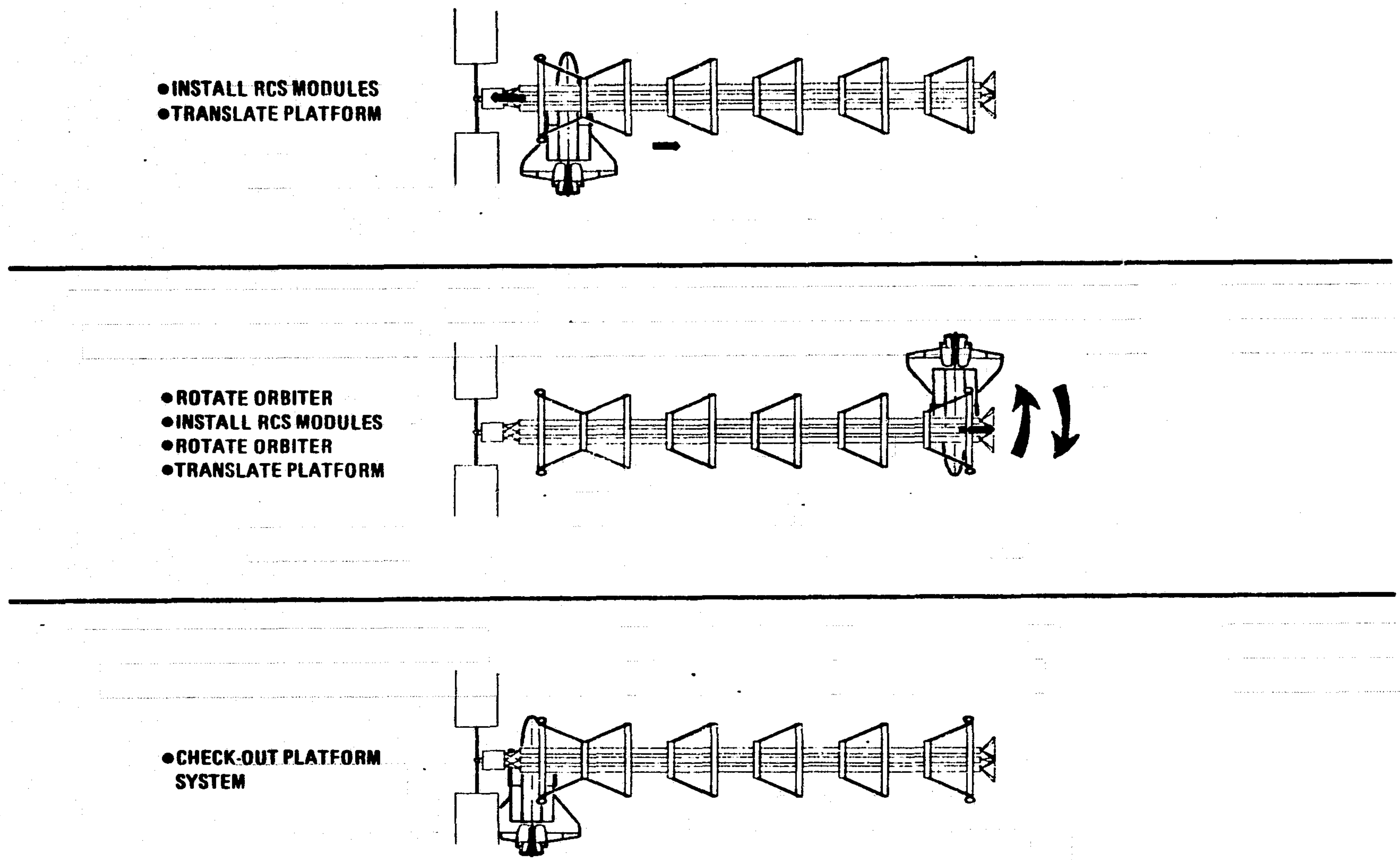

Figure 7.2-3. Third Mission Assembly Sequence

7.4 INTEGRATION ANALYSIS

The integration analysis process for the third mission closely followed that for the second mission. A complete integrated activity timeline was prepared, and the power profile and energy analysis was developed for the complete mission, as required to complete the basic platform. There is volume and weight capacity in the orbiter payload for an as yet undefined type of payload (e.g., antennas) for the platform. However, the construction analysis was performed without considering such payload installations, timelines, power, energy or crew utilization.

7.4.1 Timeline Analysis

The integrated activity timeline for the third mission appears in Figure 7.4-1. The construction time is much shorter than for the previous missions, and the functions are small in number. Considerable time is spent in translation and rotation of the platform with respect to the orbiter because of the locations of the RCS pods at opposite ends of the platform. Only two EVA work shifts are required, and the EVA astronaut can hardly be described as busy during the last one. If payload installations were included in this mission, a higher utilization of crew time might be expected, as these payloads would be installed by stopping along the path of translation between the forward and aft RCS pods.

7.4.2 Crew Activity

Because of the reduced workload, a crew of four was selected for the third mission. As before, the crew consists of two teams of two persons, one IVA and one EVA astronaut. Crew activity scheduling generally follows the concept shown in Figure 5.4-5. That is, a four-man crew is set up in two teams of two men each. Since the mission requires such a short duration, the nominal standard crew of four in the orbiter appeared to be adequate. In fact crew size is not a significant driver in this mission.

7.4.3 Lighting and Television

Lighting and television viewing requirements for the third mission are similar to those for the second mission, which were graphically summarized in Figure 6.4-2. The only new requirements concern installation of the RCS pods at the ends of long crossbeams. Considering the short duration required for this mission, such work could well be done on the daylight side, with little penalty. However, it is expected that adequate light will be available on the construction fixture and in the payload bay to grapple the pods and transport them to their respective attachment ports. If final closure and alignment is to be done in darkness, some special provisions for lighting locations might be required on the cherry picker, the RCS pods, or the structure. One or more extendable stanchions could be the solution for this problem. The light holder device may need to be adjusted by the astronaut prior to his final approach and berthing, since there is a strong chance there could be an obstruction during the prior grasp and transport phase. In contrast to the current design locations for the open cherry picker (behind the EVA operator) a location above and forward may be preferred for this particular activity.

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MISSION TIME - G.E.T. 0

ACTIVITY

41.0 PREPARE CONSTRUCTION SYSTEM

42.0 INSTALL RCS MODULES

43.0 TRANSLATE PLATFORM

44.0 ROTATE 180°

45.0 PLATFORM CHECKOUT

EVA ASTRONAUT No. 1

EVA ASTRONAUT No. 2

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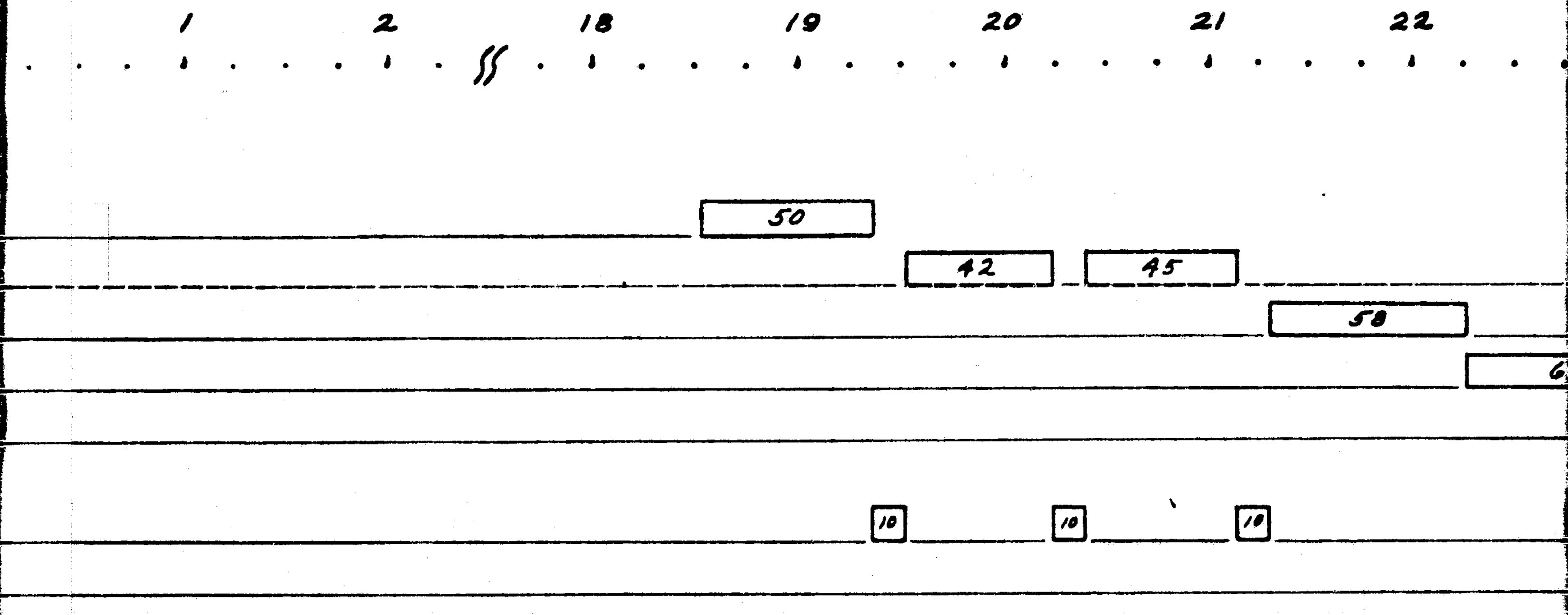

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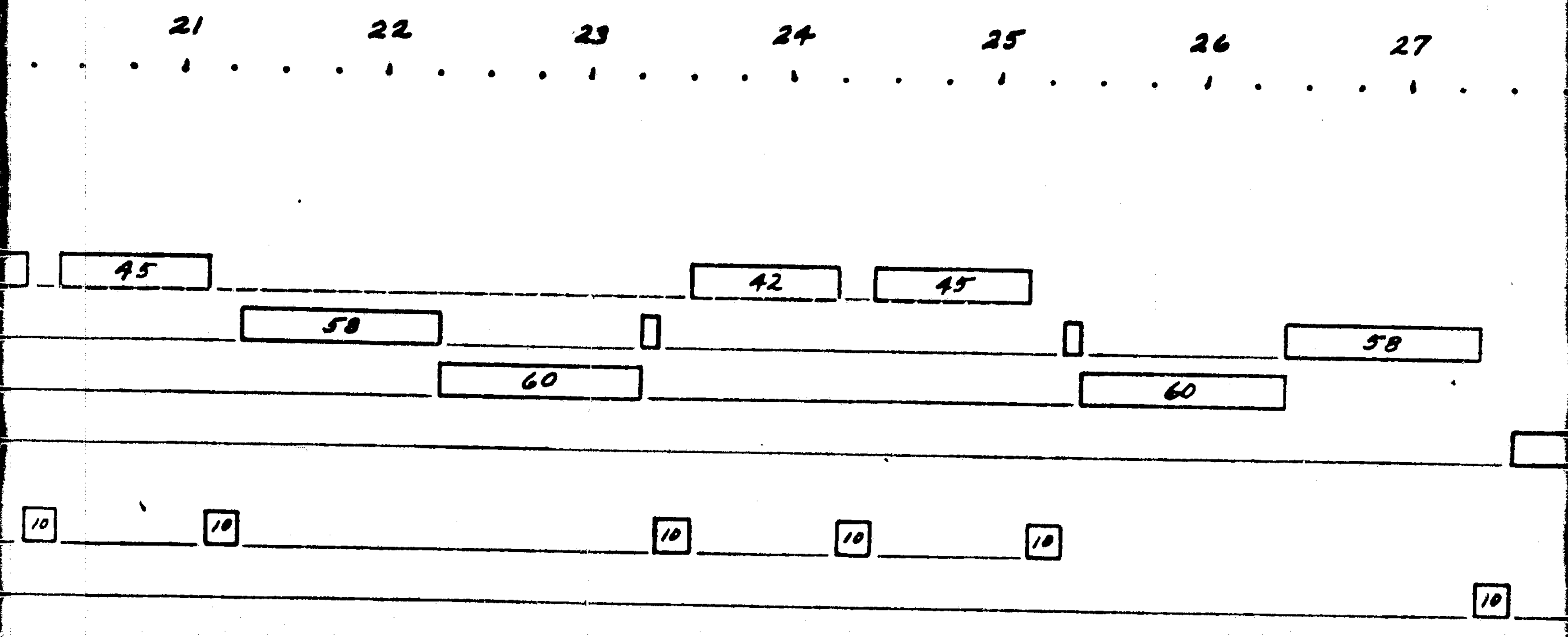
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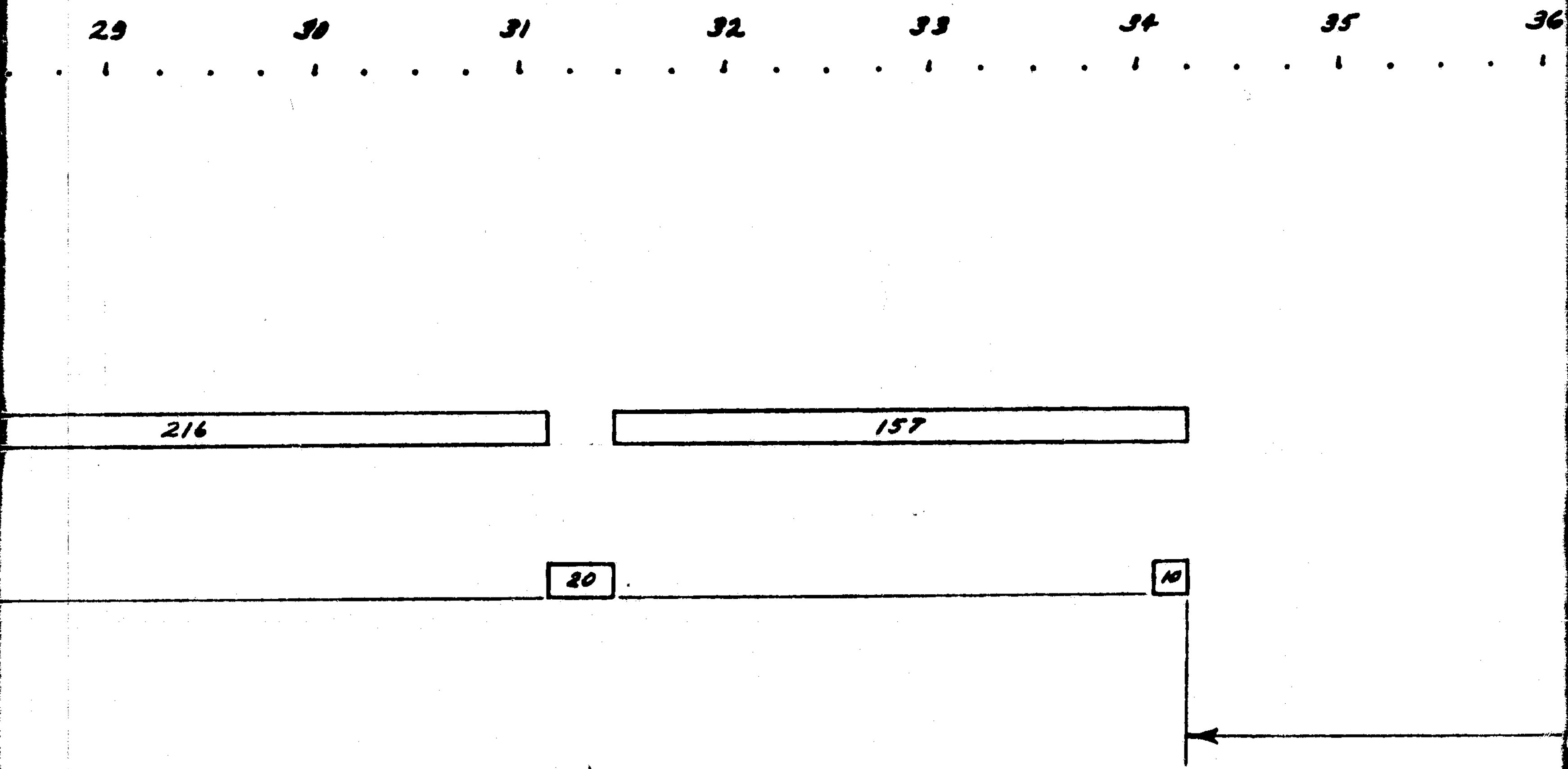
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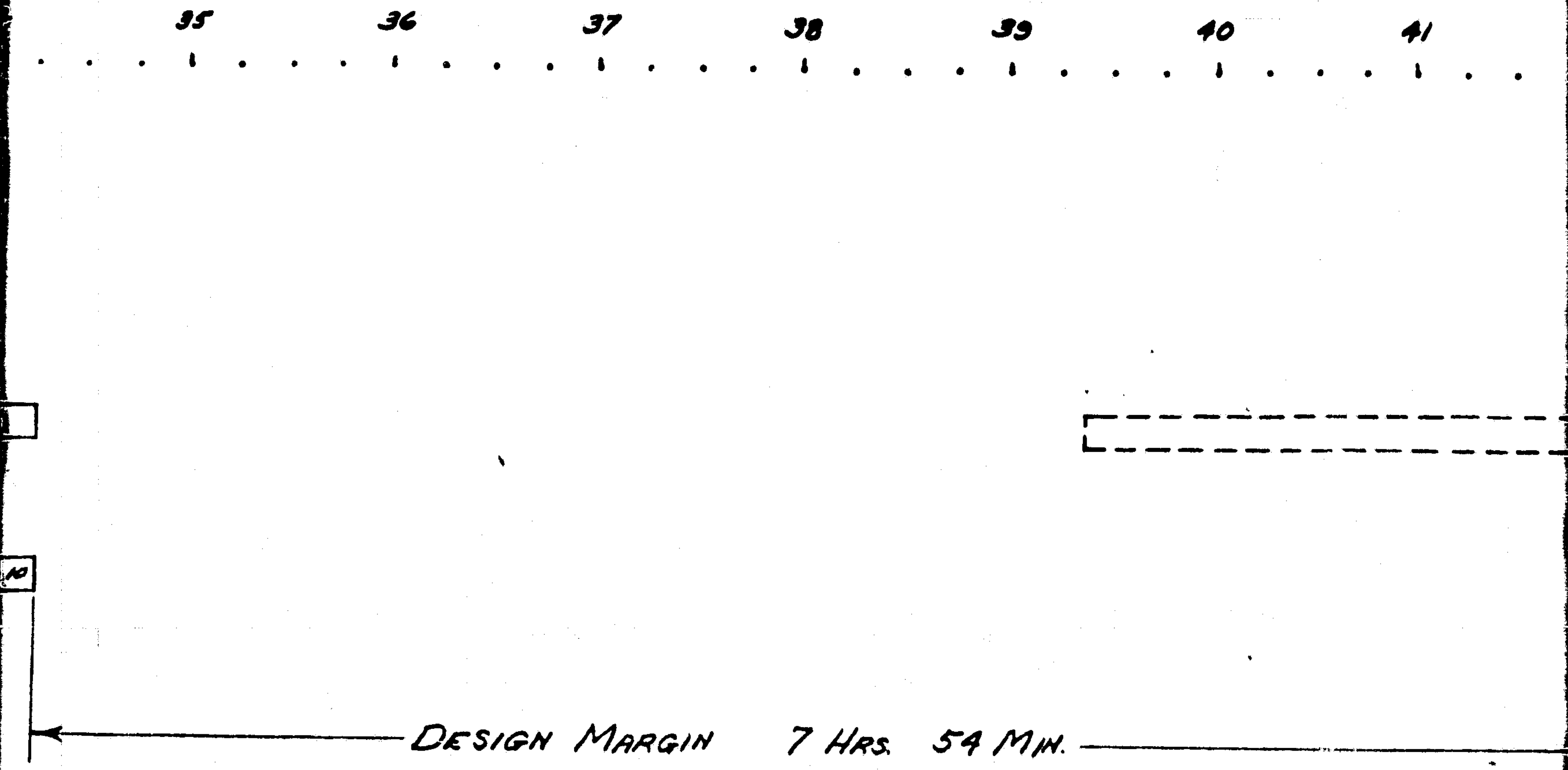

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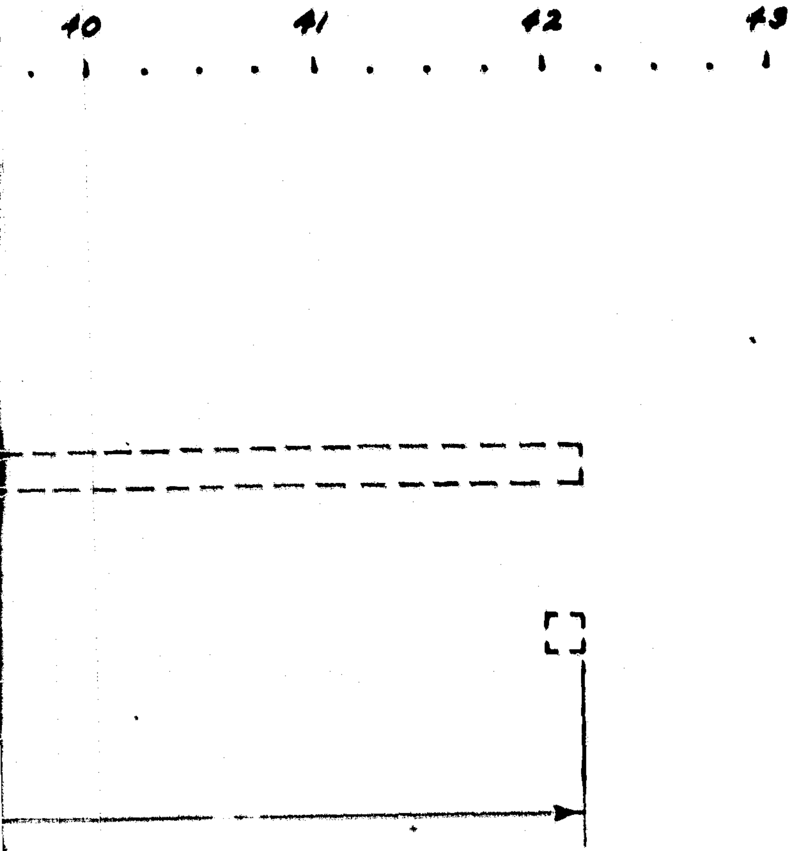

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Figure 7.4-1. Integrated Activity Timeline - Third Mission

Such a location would place the lamps closer to the berthing interface and would permit easier reach and control by the cherry picker operator.

Deployment of the solar array should definitely take place in daylight because of the great length of the array. Attempting to illuminate the surface of the array would require two or more searchlights of considerable weight and high power requirements. Such lighting provisions are not considered cost effective.

7.4.4 Power and Energy

The power profile for the third mission is illustrated in Figure 7.4-2. The highest potential power demand occurs during activation of the platform systems using orbiter power; however, the uncertainty of this demand is rather high. It is likely that power can be applied to only a portion of the systems at a time in order to avoid exceeding the orbiter 7-kW limit. Total power and energy requirements are listed in Table 7.4-1.

Table 7.4-1. Total Energy and Average Power--Third Mission

Activity Segment	Duration (hr)	Energy Required (kWh)	Average Power (kW)
• Initial activity - IVA first translation	0.83	1.65	1.99
• EVA - RCS installation	8.00	15.09	1.89
• EVA - Checkout period	6.88	22.51	3.27
• Shutdown activity - Included in above	—	—	—
Nominal total energy	15.77	39.25	2.50
Design margin (50% of nominal)	+7.89	+19.63	+2.50
	23.60	58.88	2.50
Baseline magnitudes for Construction period	(0.98 days)		

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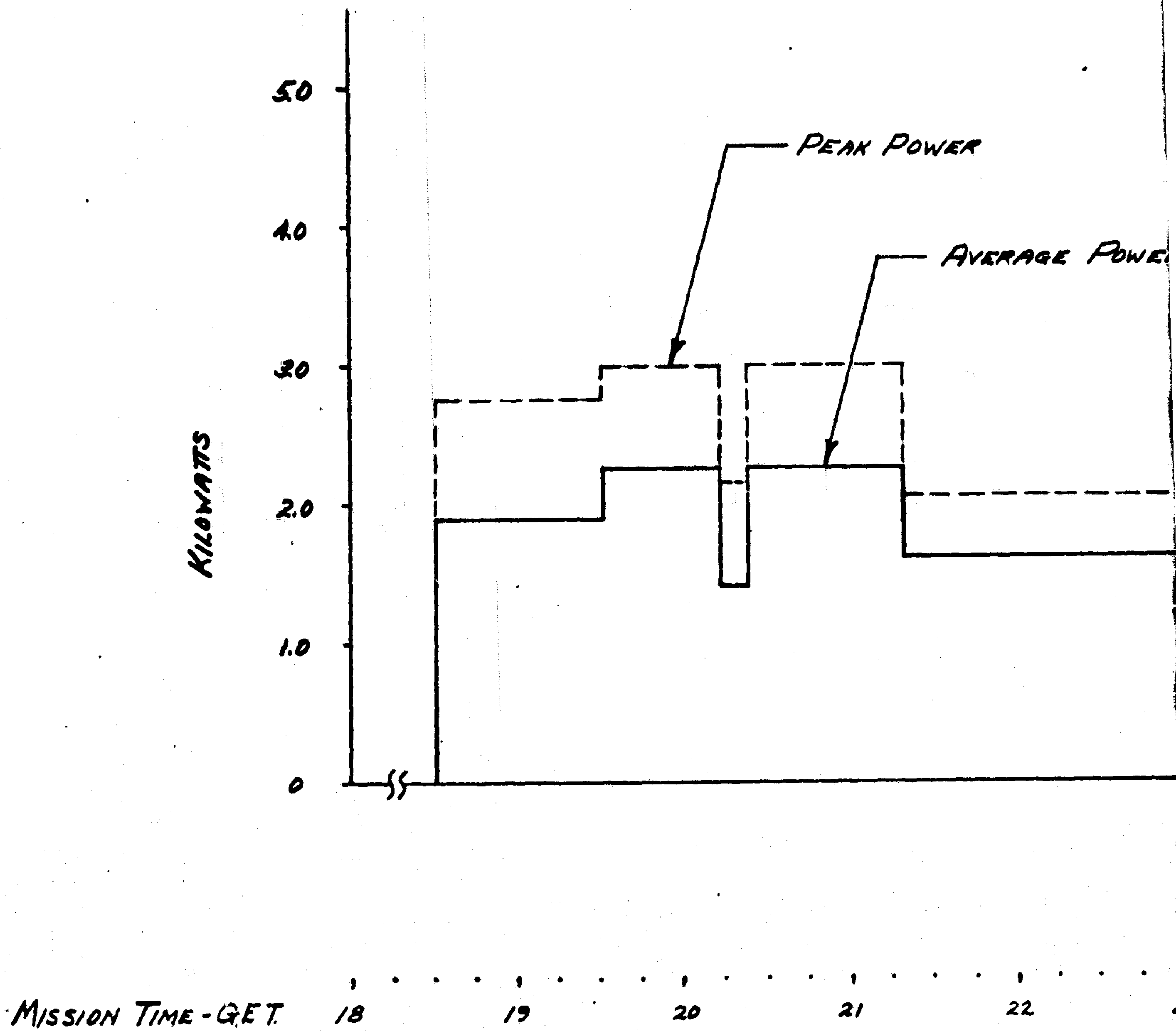

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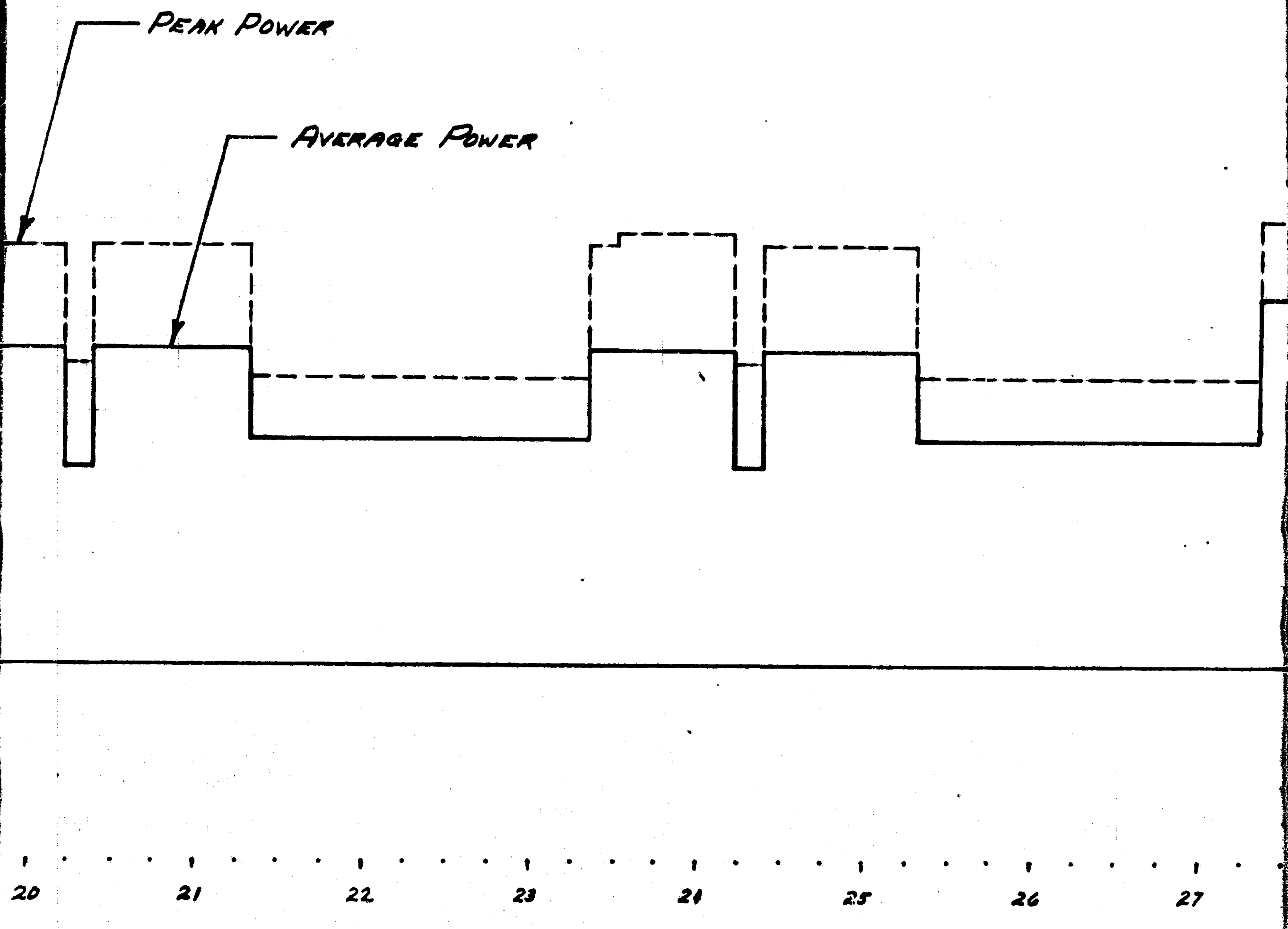

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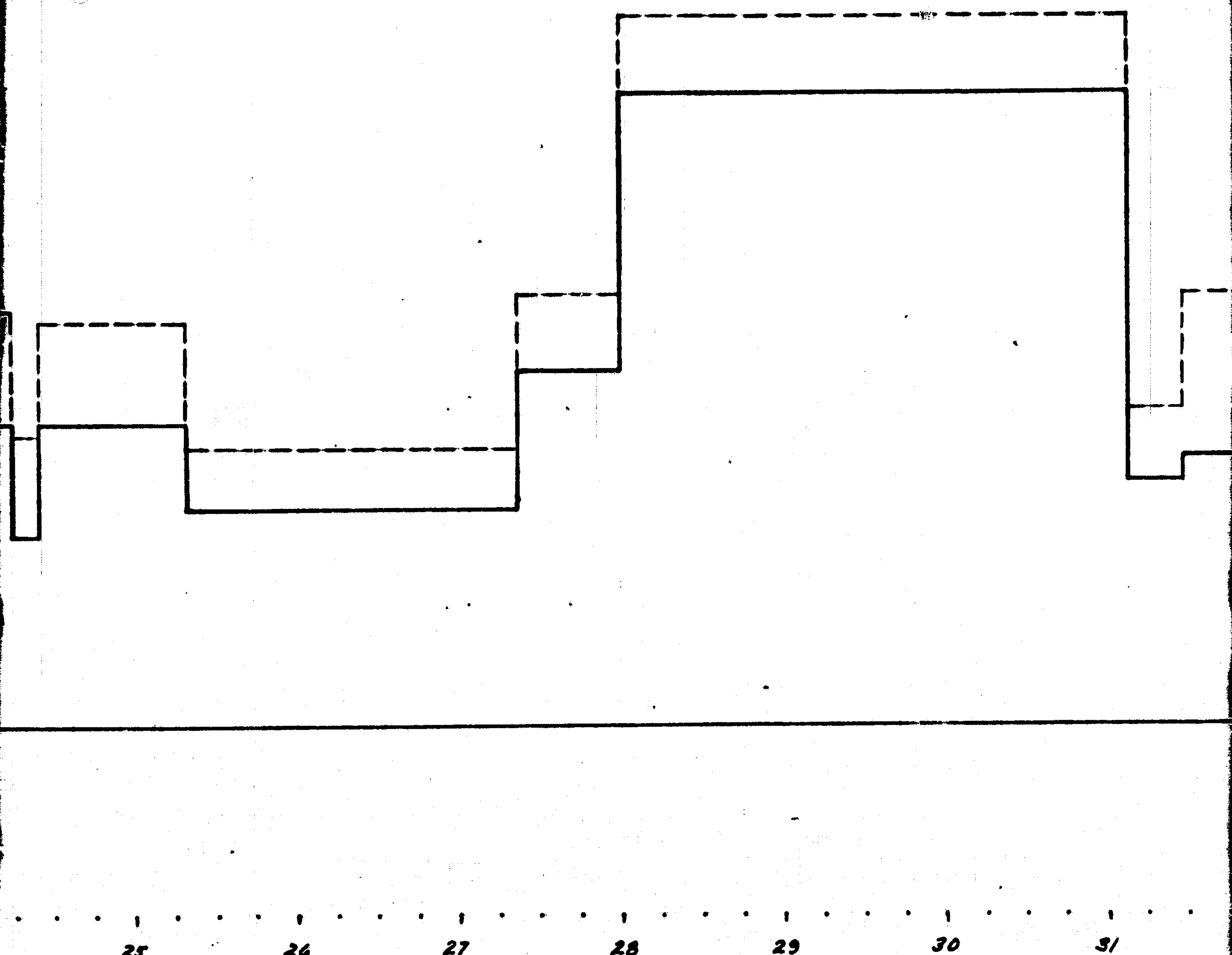

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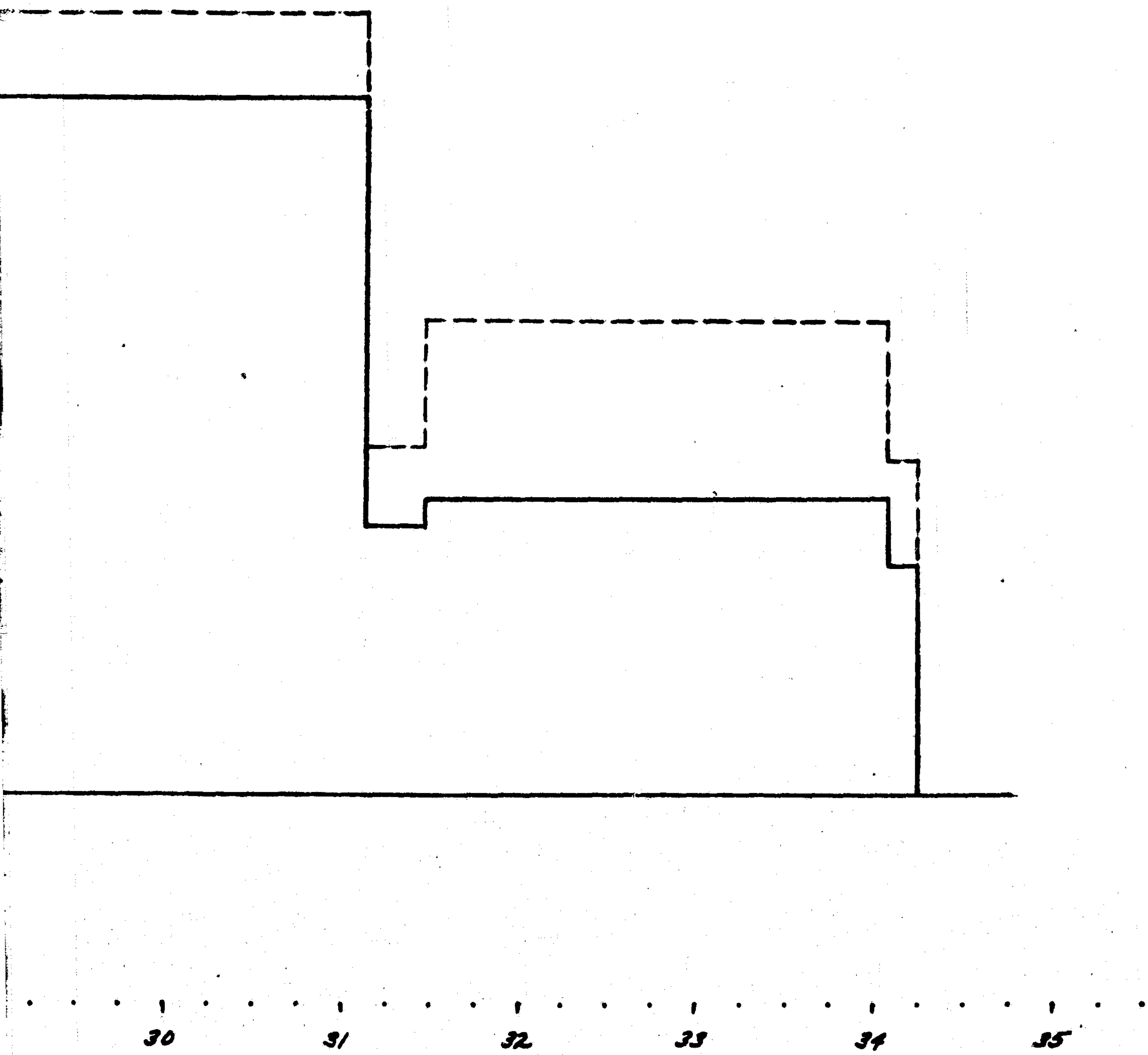

Figure 7.4-2. Power Profile - Third Mission

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7.4.5 Construction Support Equipment

Figure 7.4-3 summarizes key construction support equipment for the third mission. No new equipment items are required as compared to those for the second mission. The RCS pods are designed to have fittings compatible with the jaw end effector on the open cherry picker.

7.4.6 Flight and Site Support Equipment

The most notable new flight support item in Mission 3 is the rotating cradle support for the RCS pods in the payload bay. This support cradle concept features a revolver barrel type of mechanism which brings each RCS pod in turn to the uppermost portion of the bay to provide access for grasping by the cherry picker. This feature permits a compact stowage system in the payload bay which leaves room for additional cargo.

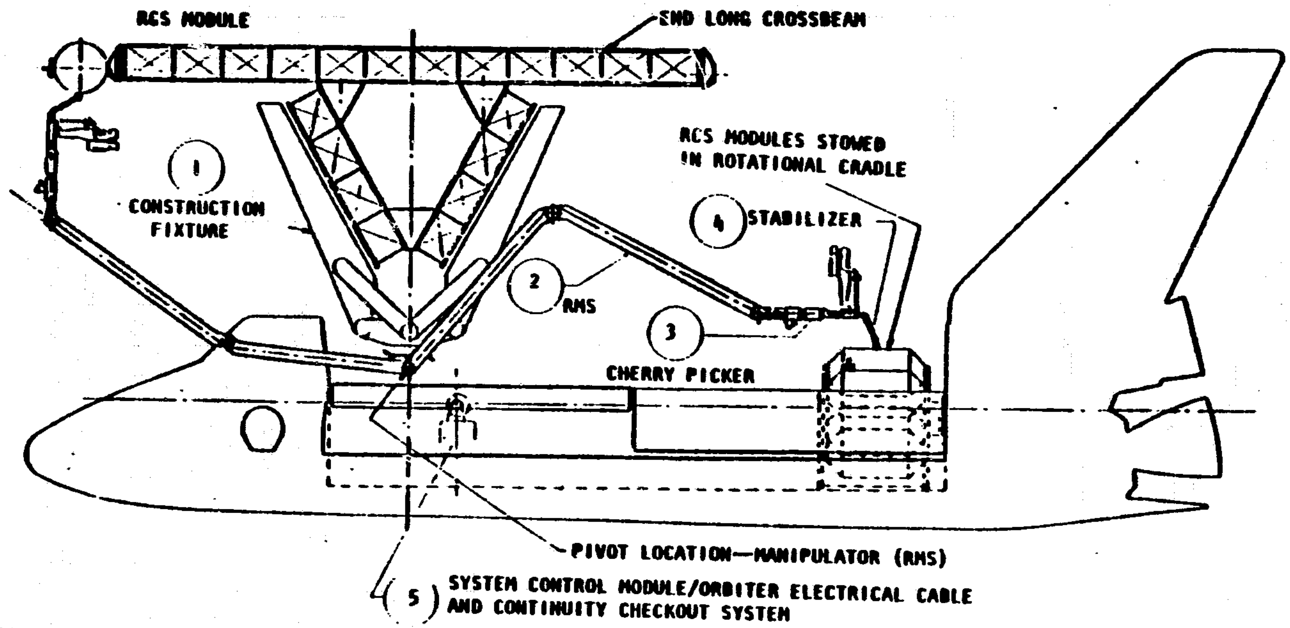
7.5 CARGO MANIFEST

The cargo types and weights for Mission 3 are summarized in Table 7.5-1; details are included in Appendix C. Figure 7.5-1 illustrates the locations of ascent boost and return centers of gravity. The ascent c.g. location is near the aft limit as currently designed; however, this can be improved by proper packaging. There is included in the mass estimate a nominal, undefined payload mass of 3,396 lb which is the remaining capability after including the required items for Mission 3.

The following assumptions were made in the development of the cargo mass statement:

1. The mission will not exceed the orbiter baseline of 28 man-days.
2. No additional airlock repressurizations are required over the orbiter baseline.
3. One additional cryo kit is included. This requirement is based on a very small identified demand over the baseline 50 kWh which is normally available to the payload. The identified demand is based on nominal requirements for construction in the third mission, plus a 50-percent design margin. If the added payload capacity is used for platform payload items (antenna, etc.), additional power would be required for such installation, thus creating a greater need for a larger portion of the kit capacity.
4. Maximum cargo weight, without OMS kit for 250 n.m. of 30,000 lb.
5. Additional payload, over the RCS modules, c.g. locates at the center of the open pay (Station 944.5).

Figure 7.5-2 illustrates the packaging arrangement of items for ascent in the payload bay of the orbiter. The hypothetical payload outline is based upon a set of communication antennas which would be installed at the ends of crossbeams on the platform. Further details are shown in Drawing No. 42662-68 in Appendix A.



I.D.	DESCRIPTION
1	CONSTRUCTION FIXTURE. SEE FIGURE 5.4-10.
2	RMS. SEE FIGURE 5.4-9.
3	MODIFIED CHERRY PICKER. SEE FIGURE 5.4-11.
4	STABILIZER. THIS BOOM IS UTILIZED FOR STABILIZING THE CHERRY PICKER DURING WORK ASSIGNMENTS. IT WILL ALSO BE USED TO TRANSPORT AND BERTH THE RCS PODS AND LARGE PAYLOAD MODULES ONTO THE PLATFORM.
5	SYSTEM CHECKOUT MODULE. THIS MODULE IS USED TO VERIFY THE SCM OPERATIONS AND ELECTRICAL CONTINUITY OF THE ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM. IT ALSO CONDITIONS POWER PROVIDED FROM THE ORBITER TO THE PLATFORM FOR SYSTEM ACTIVATION AND OVERALL SYSTEM CHECKOUT.

Figure 7.4-3. Key Construction Support Equipment for Third Mission

Table 7.5-1. Cargo Manifest Weight Summary

	WEIGHT (lb)	MASS (Kg)
Launch Mode		
Platform Items (RCS Module)	18,800	8,528
Payload (Max. for 250 n. m.)	3,396	1,541
Airborne Support Equipment	7,804	3,539
Total Cargo (Up)	30,000	13,608
Return Mode		
	11,200	5,080

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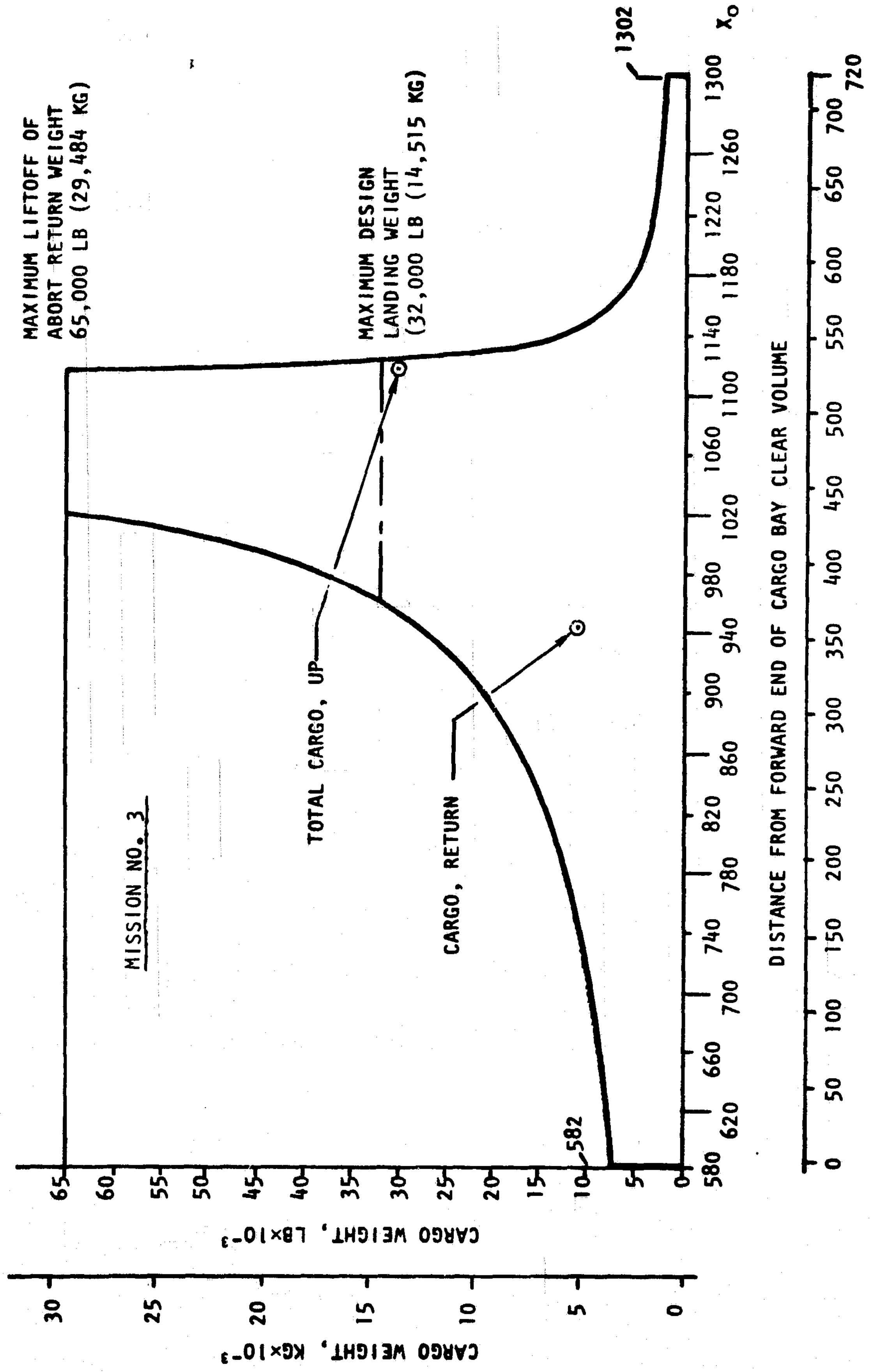

Figure 7.5-1. Cargo Center-of-Gravity Locations

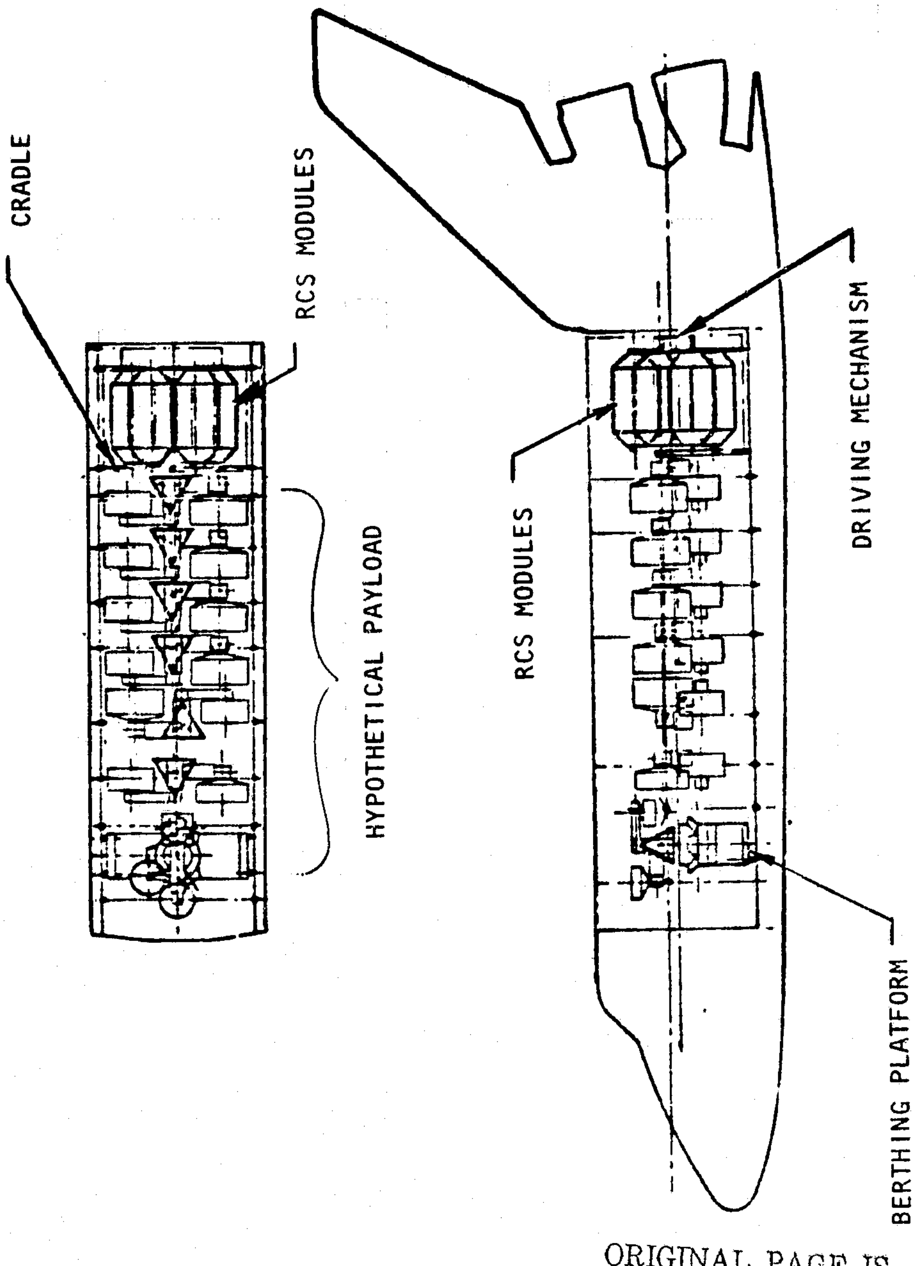

Figure 7.5-2. Third Mission Manifest

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8.0 COMPOSITE CONSTRUCTION ANALYSIS

The following material presents an overall summary of end-to-end systems analyses performed relative to construction activity. The information first presented concerns the basic three construction missions. This is followed by brief discussions of other construction activity required, such as payload installations and changeout, outfitting for geosynchronous orbit operations and installation of propulsion modules to effect the transfer to GEO.

8.1 BASIC CONSTRUCTION MISSIONS

This section summarizes results of the analyses for the three basic construction missions. The integrated timeline summary data for these three missions are listed in Table 8.1-1.

Table 8.1-1. Summary of Mission Time Required to Perform Basic Construction Missions

Mission Phase	1st Mission (Hr)	2nd Mission (Hr)	3rd Mission (Hr)
Ascent	6.3	18.5	18.5
Construction Phase	42.4	59.5	15.7
50% Design Margin	21.2	27.3	7.9
Delay for Deorbit (Includes 5.0 hr Bar-B-Que)	22.7	10.1	26.9
Descent	1.6	1.6	1.6
Total Mission Duration	94.2 (4 Days)	117 (5 Days)	70.6 (3 Days)

Tables 8.1-2, 8.1-3 and 8.1-4 present analyses of several types of construction activity timeline concerns specific to the first, second and third construction missions, respectively. Among these are the distribution of IVA and EVA man-hours, and the total hours allocated to structural fabrication and assembly (machine time), to module installation, to transport operations and to electrical lines installation. Also shown are the durations required for setup, shutdown and checkout operations. As a basis for comparison, the activity durations are expressed as a percentage of the total elapsed time for construction time on orbit. Note that when two or more similar operations occur in parallel, the total of machine hours can be greater than 100% of the total elapsed time. Power and energy data for the three missions are summarized in Table 8.1-5.

Table 8.1-2. Mission Time Analysis for Construction —First Mission

	Hours Required	Percent of Total Construction
EVA: man-hours	31.65	42.7
IVA: man-hours	42.43	57.3
Total man-hours	74.08	
Structural fabrication and assembly —machine hours	47.76	112.6*
Transport—machine hours	39.55	93.2*
Electrical lines installation	7.2	1.7*
Construction setup (elapsed)	3.27	7.7*
Construction shutdown (elapsed)	2.28	5.4*
Checkout—work hours	1.09	2.6*

*Percent of elapsed construction time (42.43 hr). Parallel operations of different equipment can result in total machine-hours larger than elapsed time for construction.

Table 8.1-3. Mission Time Analysis for Construction - Second Mission

	Hours Required	Percent of Total Construction
EVA: man-hours	44.17	42.6
IVA: man-hours	59.53	57.4
Total man-hours	103.7	
Structural fabrication and assembly —machine hours	7.76	13.0*
Module Installation - machine hours	.50	.8*
Transport—machine hours	30.41	51.1*
Electrical lines installation	1.32	2.2*
Construction setup (elapsed)	9.13**	15.3*
Construction shutdown (elapsed)	2.03	3.4*
Checkout—work hours	7.34	12.3*

*Percent of elapsed construction time (59.5 hr).
**Includes 7-hr calibration period for alignment measurement instrumentation.

Table 8.1-4. Mission Time Analysis for Construction - Third Mission

	Hours Required	Percent of Total Construction
EVA: man-hours	3.92	19.98
IVA: man-hours	15.7	80.02
Total man-hours	19.62	100
Structural fabrication and assembly —machine hours	0	0 *
Module Installation - machine hours	.53	3.4*
Transport—machine hours	7.37	46.9*
Electrical lines installation	0	0 *
Construction setup (elapsed)	1	6.4*
Construction shutdown (elapsed)	.25	1.6*
Checkout—work hours	4.87	31.0*

*Percent of elapsed construction time (15.7 hr).

Table 8.1-5. Summary of Construction Power and Energy —Basic Construction Missions

	Mission 1	Mission 2	Mission 3
Total energy (kWh) (includes 50% design margin)	217	172	58.9
Average power (kW)	3.4	1.98	2.50
Peak power (kW)	8.5	3.2	5.3

A significant result of these analyses is that transport time constitutes a large portion of construction time. Clearly, efforts to reduce transport can have a major effect on reducing on-orbit construction time.

8.1.1 Crew Assignments

A crew of six persons works three 8-hour shifts per day in Missions 1 and 2, in teams of two men each. However, in Mission 3, only four persons are required in the crew, and only two shifts of work are required.

The work shift time allocation for IVA crew includes actual construction work as well as a small amount of orbiter housekeeping time. The multiple shift operations postulated for all missions required some multiple use of sleeping stations. Considerable time is required at the beginning of each mission to set up each team of two persons for each shift.

These shift concepts require training of IVA crew members and EVA crew members to be able to accomplish the specific tasks planned for their shift. If delays are encountered, a different mix of tasks may be required. This concern led to the basic assumption that crew members assigned to IVA tasks should be capable of performing all the IVA tasks on their mission, and a similar requirement applies to EVA personnel.

Since several types of construction equipment require special training, it would be desirable to have the same basic crew perform similar tasks on subsequent missions. In particular, the RMS operations and the cherry picker operations require specialized simulation experience to develop proficiency. Backup crew members will be required to assure availability of trained personnel at time of flight opportunity, and protect the investment in the scheduled Shuttle flight equipment. All crew members must be selected with reference to their skills in mechanical assembly, technical understanding of electro-mechanical systems and ability to perform fairly repetitive activities for several hours at a time during certain phases of the construction.

8.1.2 Ground Support Requirements

The construction activity on orbit is presumed to require little assistance from ground support personnel. Contingency situations which could require technical consultation are a major exception which was not considered in this analysis.

As a policy issue, NASA may desire to follow progress of the construction and utilized TV coverage for public information releases. This would require a crew to process the TV data and provide voice communications.

Each flight is treated as a normal orbiter flight as regards to turnaround activity involving refurbishing supplies and loading the payloads.

8.2 OTHER CONSTRUCTION ACTIVITIES

Following the initial three construction missions, additional flights involving construction activities are planned as a part of the overall ETVP scenario. The following sections briefly describe these other construction activities.

8.2.1 ETVP Scenario

To help illustrate the overall plan for other construction activities a brief review of the platform operations scenario is presented. Figure 8.2-1 illustrates the planned missions profile in terms of altitudes, time periods and types of operations for a scenario based on communications technology development. In addition, this program will help develop and demonstrate technology in the areas of space construction, space servicing (at both high and low earth orbit) and orbit transfer.

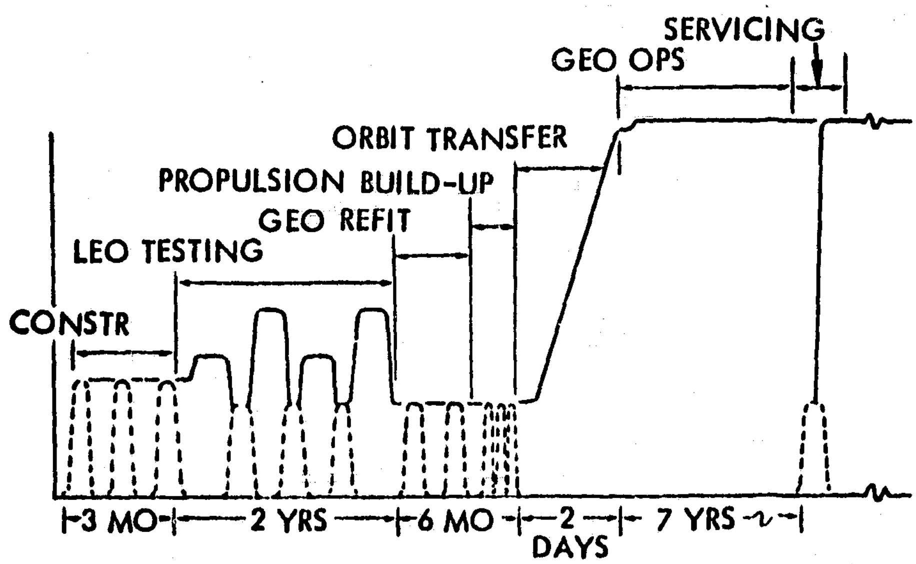

Figure 8.2-1. ETVP Mission Scenario

The three missions described in Sections 5.0, 6.0 and 7.0 are symbolically indicated at the left of the diagram. The next phase of operations emphasizes testing at various low earth orbit altitudes. During this period the orbiter will install and/or changeout various antenna payload items and may perform some servicing operations.

The next phase involves re-outfitting the platform with antenna systems appropriate to geosynchronous orbit operations, and probably changing RCS modules, batteries, gyros and other items with significantly limited life or wearout rates.

This period is followed by three flights dedicated to installing the orbital transfer propulsion modules and a final checkout. The platform is then boosted to geosynchronous orbit for operations of approximately 7 years. One or more flights for servicing or updating are expected during or at the

end of this GEO period. Such servicing may be by teleoperator or manned vehicle designed for flight to GEO.

8.2.2 Payload Installations

The platform and construction equipment designs provide for installation of payloads at 8 places, namely the ends of the four intermediate long cross beams. It is expected that such payloads will typically be some type of antenna, packaged into a compact shape for transport in the orbiter, and capable of deployment following installation. The method for installation would be similar to that for installing RCS pods in Mission 2 or that for attaching the IMU devices for measuring the alignment of the attachment ports, in which the RMS is used alone. From a construction standpoint there are significant differences in handling procedures or equipment requirements from those already described.

8.2.3 Low Orbit Servicing

The primary area of concern for low-orbit servicing is the forward assembly, which contains the electronics, and several other active components. Servicing would likely be accomplished using a cherry picker on the RMS. However, the RMS can reach each unit on the control module for removal and replacement as required.

The solar array would always be retracted to assure there would be no contact with the orbiter wing when it is performing RMS reaching operations in the vicinity of the forward assembly. In low earth orbit the orbiter berths to the construction fixture as for Missions 2 and 3. The construction fixture can also be used to translate the platform so as to provide RMS/cherry picker access to any of the payload attach ports or to the TT&C antenna at the aft end of the platform.

8.2.4 High Orbit Servicing

Provisions for teleoperator docking are incorporated near the end of each long cross beam and at three locations on the system control module. These are the main provisions for servicing at geosynchronous orbits or at lower orbits not reachable by the orbiter. It is assumed the teleoperator will incorporate a manipulator arm capable of reaching the short distance from the docking port to the items in question, in order to perform removal and replacement.

In some cases during the low earth orbit operations servicing may be accomplished by flying the platform (using RCS) to a lower orbit so as to facilitate orbiter servicing methods and equipment.

8.2.5 Propulsion Module Installations

Installation of the three propulsion modules for orbit transfer is a typical significant concern for construction. It involves the handling of a large bulky mass, from removal out of the orbiter payload bay to alignment

and berthing of the module onto the thrust structure attach port. The selected concept for performing this function is illustrated in Figure 8.2-2. The open cherry picker is used for the majority of the transport and berthing. However, the module is first deployed out of the starboard side of the orbiter payload bay by use of the payload installation and deployment aid (PIDA) arms. The starboard deployment was selected to permit grappling the module near the forward end and to avoid problems of reach or interference by the RMS arm. This location was selected for grappling to permit the EVA crew operator direct vision of the final berthing interface.

Considerable assistance would be expected by the crew in the orbiter cabin, who could observe operations with TV cameras strategically located to see critical clearance points not visible to the EVA operator.

8.3 ORBITER MODIFICATION REQUIREMENTS

The construction analysis identified three areas of concern regarding orbiter modification requirements. These are the nitrogen tank installation airlock repressurizations, the RMS mobility enhancement, and the 8-psi suit support provisions.

Additional nitrogen tanks are required to support the multiple repressurizations to perform EVA during the first and second mission. This installation requires special plumbing and tank attachments beyond the standard baseline orbiter provisions. However, the space provisions and design concepts for such modifications have been incorporated into the STS program. This is a relatively minor impact item.

The most expensive and complex modifications identified involve the RMS. These have been described and discussed in Section 5.4.5. Specifically, they include an upper arm roll joint, a wrist camera and light mount with tilt and pan capability, anti-collision software, and provisions to control the RMS from the open cherry picker.

The use of an 8-psi suit in the orbiter is likely to require new suit support provisions in the form of brackets for a larger, bulkier suit, new piping and control valves for the pressure connections, and probably provisions for a two-gas supply system for the portable life support system. In addition, some added storage capacity may be required for the larger number of suits implied in the 6-person crew concept.

8.4 CONSTRUCTION SUPPORT EQUIPMENT DEFINITION

This section summarizes the totality of construction support equipment and its usage as identified for fabrication and assembly of the Engineering and Technology Verification Platform (ETVP).

The most significant pieces of construction equipment appear in the complex of devices called Construction Station No. 1. The key elements of this construction station, which are used in all three construction missions are the building fixture yoke and the beam rollers and support arms. The

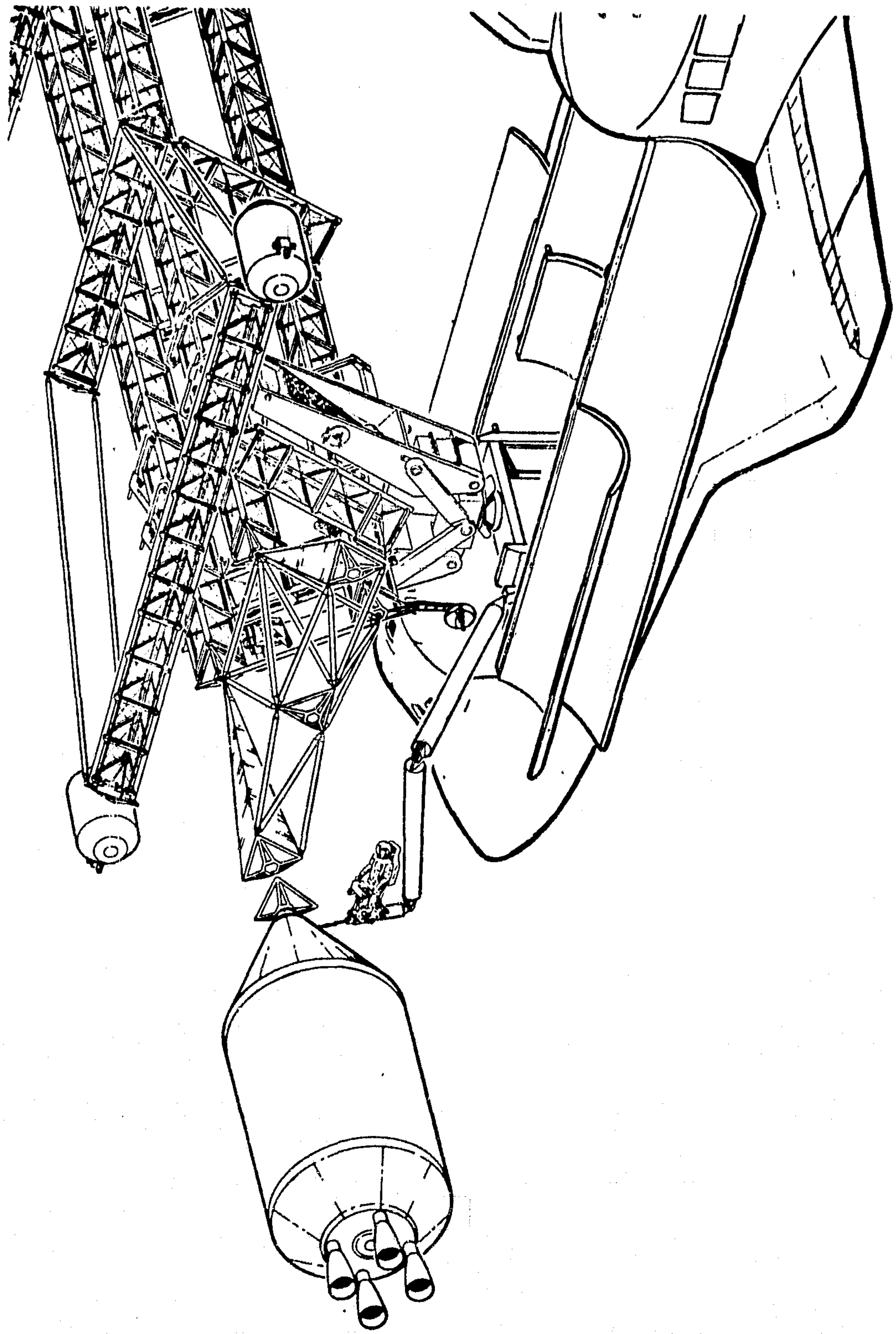

Figure 8.2-2. Installation of Orbit Transfer Propulsion Module

yoke and roller configuration define the orientation and location of the platform structure. More significantly, they facilitate the translation of the entire platform assembly with respect to the orbiter RMS such that access can be gained to all attachment ports at any time during the second and third missions. They provide for single beam translation, and thus, a desirable separation of the functions of fabrication and of electrical line installations on the first longitudinal beam in the first mission. In summary, they enable the work to be brought to a compact and efficient work space during all phases of construction. Attached to the yoke are the actual construction tools and devices which perform and facilitate construction. The major element of this set is the cross-bridge structure. Rotational and positioning capability is provided within the cross bridge to accomplish the motion requirements for the beam builder and the electric cable reel for wire run installation. The cross beam positioner mechanism and the modified cherry picker, used for astrunaut support during platform assembly, are both attached and maneuvered by drive units within the cross bridge structure.

The libration damper booms, TT&C, solar arrays and batteries are located within the building fixture and are utilized as discussed in Section 5.4.5 and in Construction Activity Data Sheet 17.1 (Appendix B).

The basic work tool utilized for parts and equipment translation is the Remote Manipulator System (RMS). A detailed description and modification requirements to this tool are covered in Section 5.4.5(a) of this report.

Additional required construction equipment for platform assembly is located at Construction Station No. 2 (Figure 5.4-12). All ETV platform long and short cross beams with end attach ports plus intersection fittings, wiring and teleoperator docking ports are assembled at this station into complete structural members prior to attachment onto the ETV platform.

The major items required for this operation are, for the most part, non-existing and therefore require new design and fabrication. The beam builder, cherry picker and the remote manipulator system, however, are under study and evaluation by their respective engineering firms. These items were designed and built to meet certain conditions, but would have to be modified in part to meet the requirements for utilization in the large space construction system as outlined in this report. The chief driver for the beam builder selection is that this machine was configured for the SCAFE program by General Dynamics to fabricate triangular light weight beams of the same configuration as those selected for the ETV platform. The Grumman designed cherry picker was chosen as a work tool because, with simple modification, this unit can support the astronaut and provide maneuverability, lighting, and work tool retention during that time when the astronaut is required to assist in the platform assembly.

Miscellaneous tools, devices and life support systems such as RMS end effectors, EVA hand tools, illumination devices, TV cameras and optical alignment devices are all considered to be construction support equipment. Detailed descriptions of the above items and other associated equipment is covered in Section 5.4.5 and Section 5.4.6 of this report.

For ETV platform verification and checkout, an orbiter supported module with an attached storage reel holding the electrical checkout cable is provided as part of the support equipment. By using the RMS supported cherry picker to perform the task of removing the hookup from the reel, and in turn attaching the cable end to the teleoperator port provided on the control module, platform functions and data continuity can be recorded.

8.4.1

Summarized in Table 8.4-1 is a listing of the construction support equipment needed to fabricate and assemble the ETV platform. The usage of the equipment is identified according to requirements for each flight, from initial construction effort, to time of vehicle readiness for delivery to a geosynchronous orbit.

8.4.2 Construction Support Characteristics for Productivity and Cost Effectiveness

The basic concepts incorporated into the construction equipment are derived from good industrial engineering practice. The major benefits are that they provide means to bring the work to a compact work place, thus reducing transportation time and reducing power requirements for lighting a large facility.

Separation of parallel functions is another principal employed to reduce time for construction. The two construction stations used in Mission 1 provide examples.

Commonality of equipment and processes is another principal leading to cost effectiveness. For example, intersection fittings and teleoperator docking ports are installed by the same machine. Use of similar attachment ports in many places is another.

The RMS end effector is, in effect, a tool for transportation and installation. Only three different types are used, the standard end effector, a beam-handling effector and the jaw end effector used on the open cherry picker.

Lights and TV camera locations are selected for multiple use and provided with tilt/pan capability for several operational viewing conditions.

Considerable automation is employed to minimize crew size and on-orbit time costs. However, the builtin dexterity and judgement capabilities of humans are used where it appears that automation would be excessively costly.

8.5 IMPACTS OF CONSTRUCTION ON PLATFORM

The construction of the platform using the orbiter as the construction facility, and the resulting construction scenario, created some restrictions to the configuration which required the development of some unique platform assembly items. Servicing operations concepts also introduced impacts to the platform configuration concept.

Table 8.4-1. Equipment Usage as a Function of Mission

CONSTRUCTION SUPPORT EQUIPMENT	MISSION USAGE					
	FLIGHT			PAYLOAD DEL./ATTACH	PAYLOAD UPDATE	OTV DEL./ATTACH
	1	2	3			
1. BUILDING FIXTURE	●	●	●	●	●	●
2. BEAM SUPPORT ARMS	●	●	●	●	●	●
3. CROSS BRIDGE STRUCTURE	●					
4. BEAM BUILDING - TRIPOD & ATTACH PORT MAG	●					
5. BEAM POSITIONER	●					
6. CROSS CORD REEL CLUSTER	●					
7. WIRE LAYING REEL	●					
8. EVA WORK STATION	●					
9. MMU/HOLDING FIXTURE	●					
10. LIGHTING	●	●	●	●	●	●
11. TV CAMERA	●	●	●	●	●	●
12. Y-FRAME SUPPORT	●					
13. INTERSECTION FITTING & TELEOPERATOR DOCKING PORT MAGAZINE	●					
14. REEL ASSEMBLY FIXTURE	●					
15. RMS	●	●	●	●	●	●
16. SPECIAL END EFFECTOR	●					
17. CROSS CORD HAND TOOL	●					
18. CROSS CORD TETHER	●					
19. ELECTRO-OPTICAL STRUT ALIGNMENT DEVICE	●					
20. CHERRY PICKER WITH STAB. ARM & RMS END EFFECT.		●	●	●	●	●
21. STRUT LENGTH ADJUST. DEV.	●					
22. IMU & BASELINE MOUNTING FIXTURE		●				
23. CHECK OUT CABLE & MODULE		●	●			
24. HAND OPERATED STEM DEVICE		●				

8.5.1 Basic Configuration Impacts

The basic configuration was influenced initially by the use of the orbiter as the construction facility. The principal influence was the reach capability of the RMS. Larger tri-beam sizes were also impacted by the orbiter payload bay size and the packaging complexity of the fixture that would be experienced. The platform size as defined in this study is, however, quite satisfactory to perform the anticipated missions.

In order to minimize the construction time for certain operations, such as installing the bracing struts, the orbiter was positioned so that more than one installation could be accomplished from a single position. Consequently, the lengths of the long cross beams were restricted in order to accommodate this goal, and the distance between cross beams was also influenced.

The in-plane cross beam arrangement was influenced by the desire to minimize fixture complexity and construction time. Variations to the end bays of the short cross beams was required in order to achieve the in-plane cross beam configuration. The end bay configuration changes were coordinated with General Dynamics concurrence was received that the changes were feasible with little impact to the basic beam builder.

8.5.2 Joints and Connections

The structural joint utilized between the longitudinal beams and the cross beams resulted from the desire to minimize construction time and to minimize complexity. An alternate joint (welding of the beam caps) required weld equipment with complex multi-motions to reach the contact surfaces. Access to these areas was also marginal. The development of the intersection fittings solved the problem of complexity of the joining equipment and reduced the time required for the joining operation (Figure 8.5-1).

The attach port concept was the result of developing a port that could efficiently transfer loads into the beams, be adaptable to various functions, and package efficiently in the orbiter cargo bay. The truss type port utilized on the platform contains these capabilities.

Two unique types of electrical connectors was identified as a result of construction concepts. The installation of the electrical lines in an automatic mode requires the automatic connection of lines to interface connectors. The interface connectors are required to mate with the RCS modules and with payloads. The interface connectors are also unique because they are actuated on command after the RCS module or payloads are mated to the attach ports (Figure 8.5-2).

The other unique connector was involved with the EVA mode of mating the electrical lines between the longitudinal run and the cross beam run. These connectors must be sufficiently large to accommodate the gloved hand of the EVA crewman. In addition, automatic final mating of the connector was desirable. The connector concept developed for this function has these

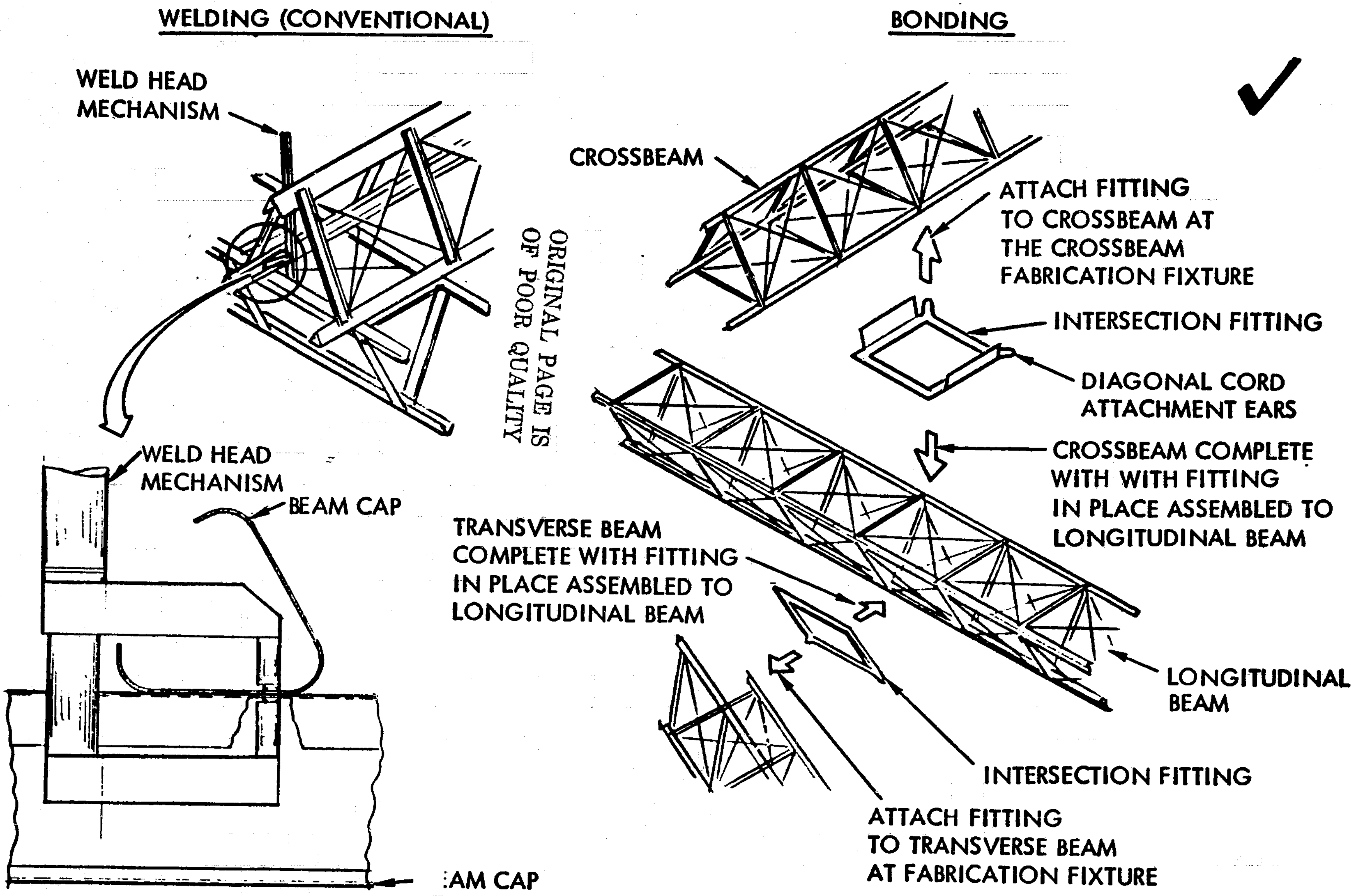

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Figure 8.5-1. Beam-to-Beam Joining Concepts

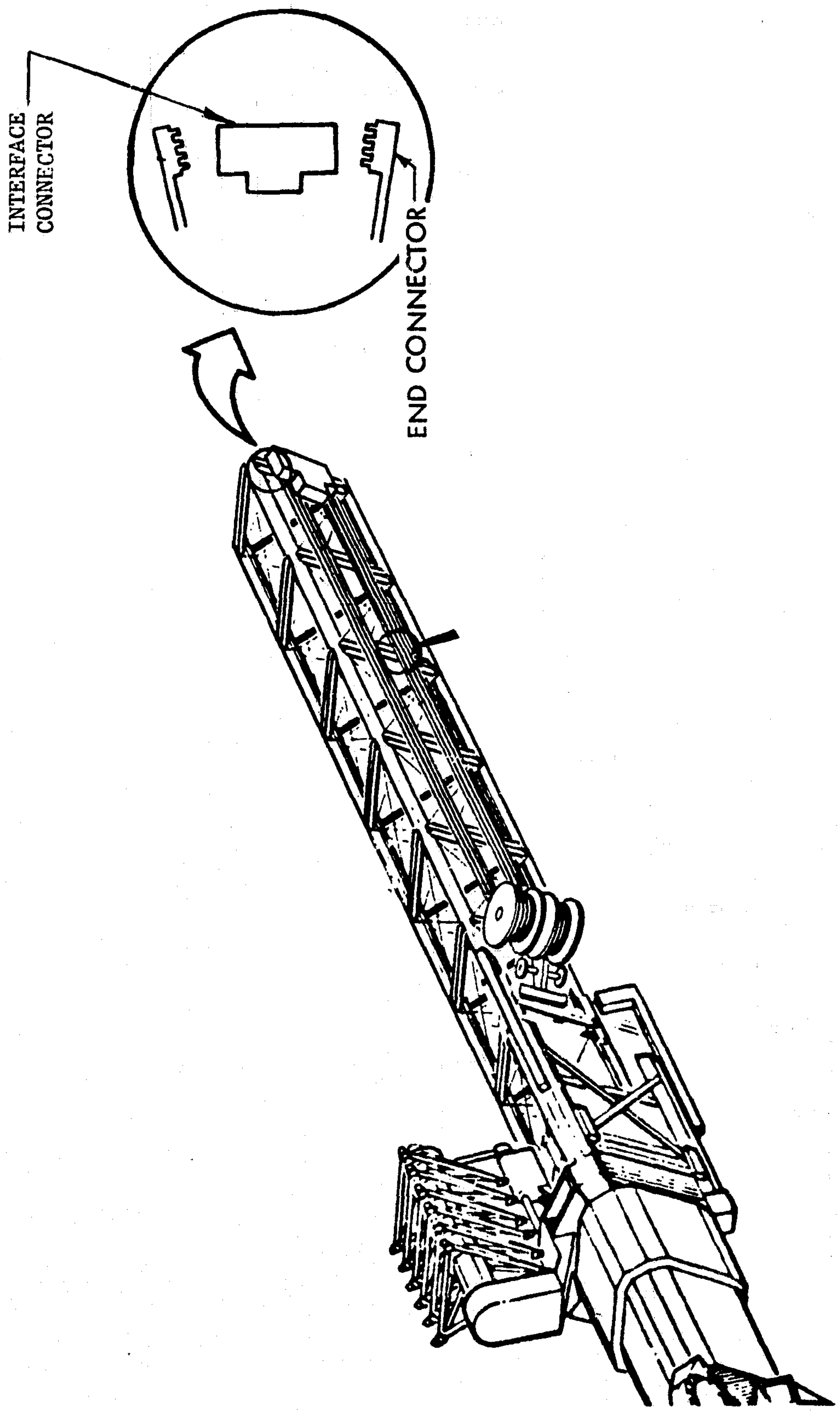

Figure 8.5-2. Automated Connector Concept

characteristics. The astronaut inserts the guide probe into the mating half, releasing a spring which drives the two halves of the connector together (Figure 8.5-3).

8.5.3 Modularity of Systems

Modularizing components and systems resulted from the desire to simplify the installation process, and to define a feasible servicing concept. The RCS modules are a self contained unit including propellant, engines and controls and requires only the automatic mating of power and data lines. A similar concept is utilized for the components installed on the SCM. The SCM components are packaged principally to effect the servicing function of removal and replacement by use of the orbit RMS or by a similar device on a remote or manned servicing vehicle in GEO.

The modularization of the total SCM including the solar array panels and rotary joint provided an efficient package for orbiter payload bay stowage. A single installation activity utilizing the RMS and cherry picker assisted EVA astronaut installs the total SCM on to the platform (Figure 8.5-4).

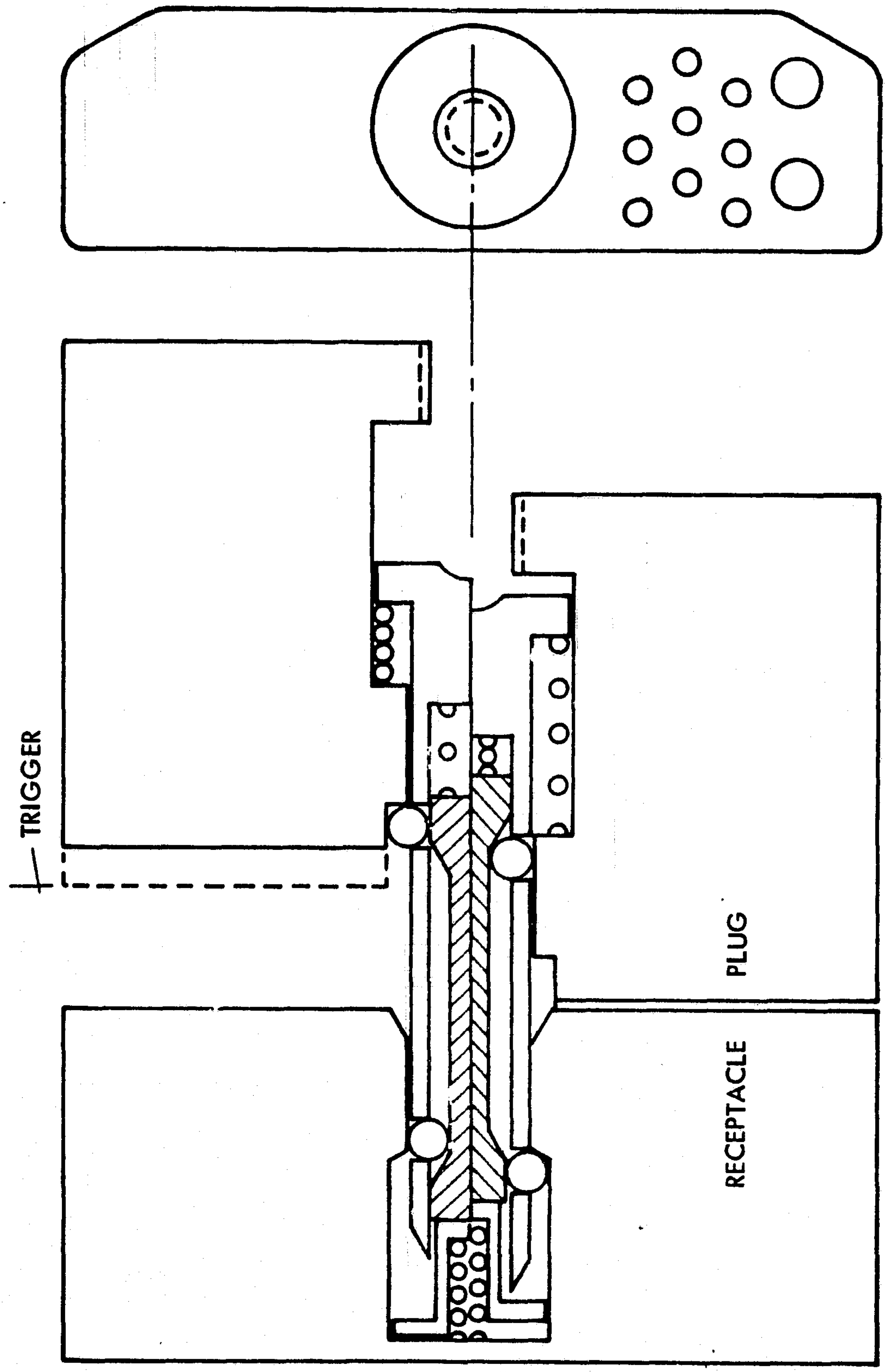

Figure 8.5-3. Self-Insertion Connector Concept

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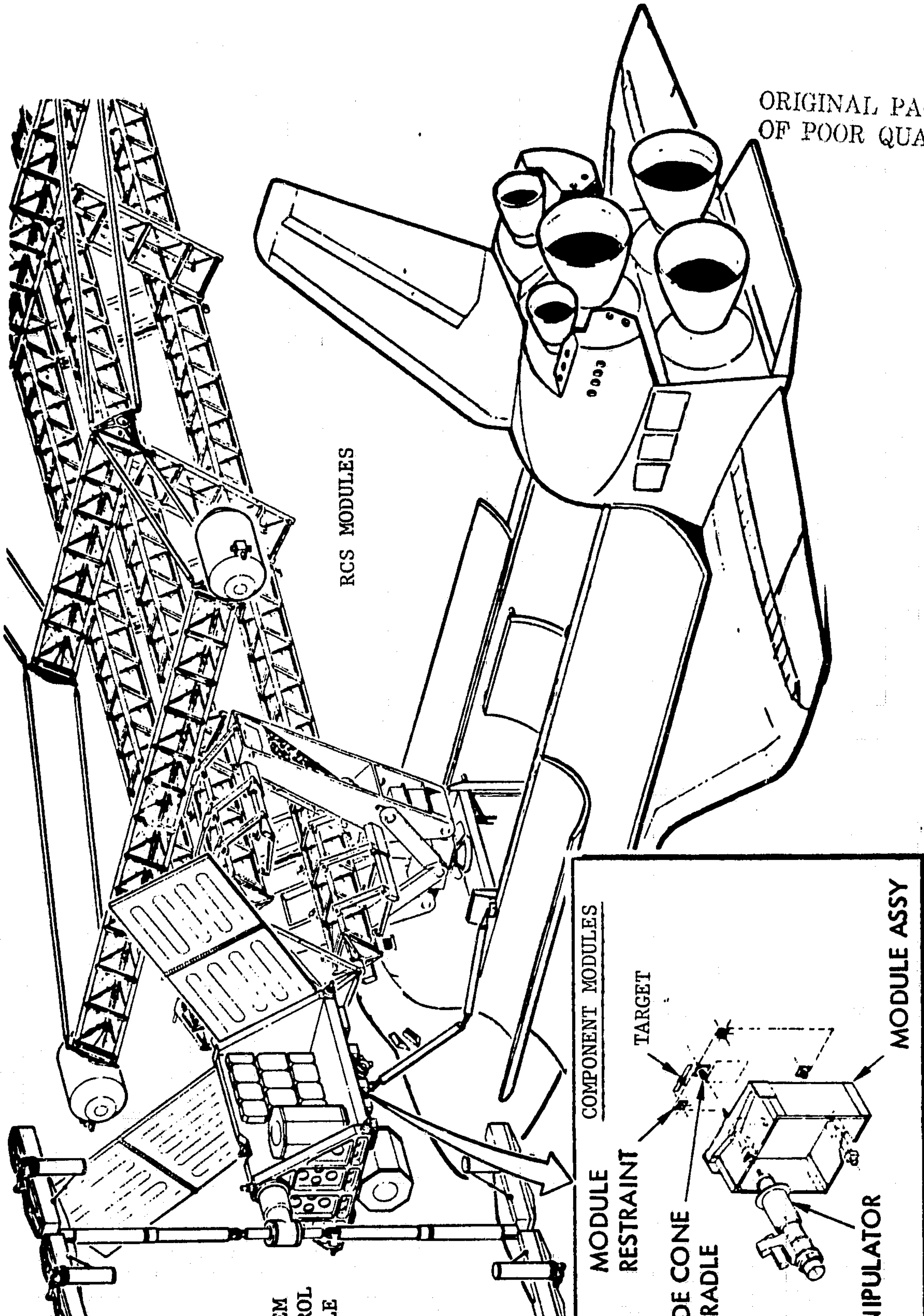

Figure 8.5-4. Modularity

8.6 CONSTRUCTION RESOURCE UTILIZATION

A key issue in space construction is utilization of the available resources. Typically, these consist of basic supplies and additional kits which can be added to supplement nominal mission capability, such as time on orbit, payload power, or number of crew. A major concern is the amount of materials which can be carried up in the orbiter payload bay. These limits may be determined by the orbiter lifting capability or by the payload bay volume. Figure 8.6-1 summarizes four specific areas of interest in resource usage. Each of the four bar charts depicts a percentage utilization for each of the three construction missions.

The upper two charts indicate how much of the possible capacity of the orbiter weight lifting capability and payload bay volume are used in each mission. In the sense defined for this preliminary analysis, the first two missions are volume limited. That is, various construction fixtures, materials and equipment are loaded into the payload bay until the next logical item to be installed will not fit into the bay. The third mission only utilizes about a third of the payload bay volume for construction. Thus, there is space for platform payloads or other concurrent mission payloads, if desired (satellite launch, for example).

8.6.1 Kit Utilization

In the discussion of power and energy demand analysis it was pointed out that all missions required a cryogenic kit (hydrogen and oxygen) to provide enough power and energy for the construction activity. If one considers what could have been installed as a fuel kit without impacting the payload bay volume, the maximum is actually two kits per flight. The lower left corner of Figure 8.6-1 uses the two kit basis of 100% of capacity, and compares the calculated energy usage as a percentage of the energy available in the kits. The conclusion is that there is a healthy margin of energy available to accomplish the missions. In fact, in the third mission it would not be necessary to install the cryo kit if the 50% design margin had not been considered. (The actual calculated magnitudes for power and energy utilization for the three missions are summarized in Table 8.1-3.)

The power rate is another type of resource related to energy. As previously noted, the nominal 7 kW limit for orbiter payload power usage was occasionally exceeded in the first mission for a short time. Therefore, one could say the power resource was a limiting factor in construction for this mission, since some rescheduling might be required to avoid such exceedances.

Another kit requirement is the added nitrogen for airlock repressurizations to support the extensive EVA. The current orbiter capability of two 2-man EVA's for mission operations will not be adequate. However, additional Shuttle-type nitrogen tanks can be used, each providing nitrogen for approximately 4.5 repressurizations of the airlock. Since up to eight airlock cycles are required for the most demanding construction mission, two additional tanks will be required. This would give a total of 11 repressurizations (4.5 from each new tank plus the two provided by the baseline orbiter).

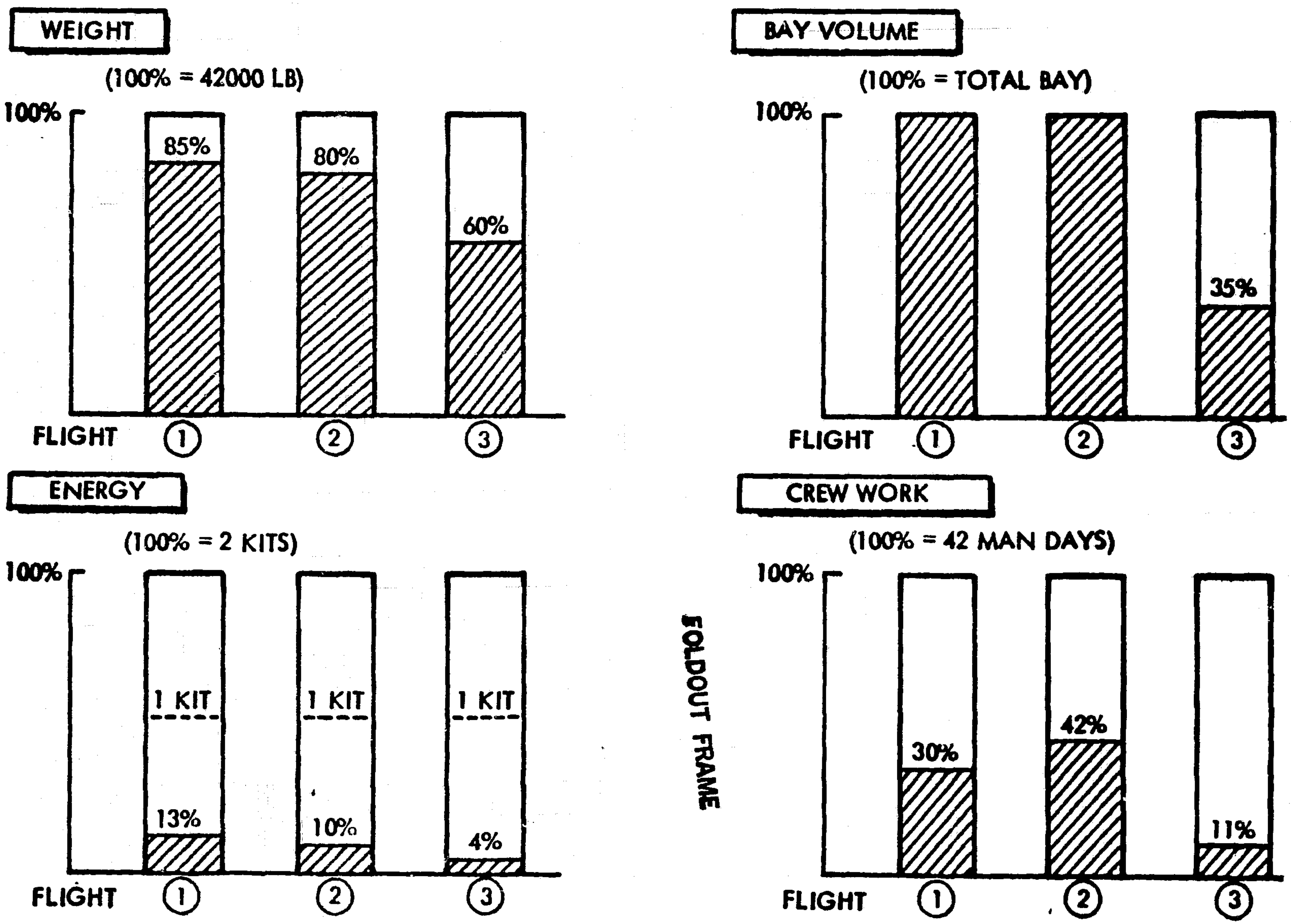

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Figure 8.6-1. Resource Utilization Summary

It is estimated that up to 12 nitrogen tanks could be located beneath the cargo bay liner in the space designated for the fifth cryo energy tank set. Since the added cryo is not needed for the ETVP construction missions there is more than ample space for the required two additional nitrogen tanks. Even with the fifth cryo tank set installed there is ample volume for additional nitrogen tank installations, but they are located in more difficult locations. Modifications to the orbiter will be required for tank mounting and to provide the necessary fluid interfaces.

8.6.2 Crew Utilization

The subject of crew utilization is at once a vital one, and yet one difficult to accurately quantify. The graph at the lower right of Figure 8.6-1 shows the 100% level as 42 man days. This figure is based on the concern that costs for extra supplies become excessive after nine days, and that one day is required to ascend and another to descend. The remaining time, seven days, is available for construction work by the crew of six. It is also a convenient nominal maximum in that the stowage provisions in the cabin are nominally designed to accommodate 42 man days.

The aforementioned graph indicates that the construction work time requires less than half the available 42 man-days. This implies a healthy margin exists for construction crew workload planning. Such a margin can provide for uncertainties in actual construction task workloads and may further allow consideration of the use of the currently planned 4-psi suit as a backup to the study baseline 8-psi suit. Construction productivity is reduced with the 4-psi suit because of pre-breathing requirements. Thus, the crew workload margin may offer the possibility in program planning of having a mission backup capability in the event funding and/or technical difficulties impact the availability of the 8-psi suit.

8.6.3 Uncertainties

The subject of resource utilization cannot be completely discussed without some acknowledgement of the uncertainties of the estimates used to evaluate the system. Table 8.6-1 summarizes the two major types of uncertainties, design margin and contingency.

Because of the preliminary nature of the analysis and its dependence on predicted characteristics of machines and procedures not as yet developed, the design margin of 50% may be highly optimistic. In fact, little experience is available to quantify crew pauses and planning time in using the RMS for construction types of activities. The translation times are also subject to considerable error, although these times are perhaps the best known. Actual process times are also gross estimates in many cases. The beam builder machine is a key factor and has been the subject of considerable study. Yet, it has not been proved in actual space construction. The power estimates for lighting are admittedly highly optimistic in their frugality, and could be a major factor in causing power peaks which would tend to reduce parallel operations. Power for the construction machinery might be considerably above the estimates used if further analysis proves that heaters are needed for much of the machinery proposed.

Table 8.6-1. Uncertainty Issues

Uncertainty	Considerations	Used	Maybe
Design Margin	o Crew Time o Translation Time o Process Time o Lighting Power o Process Power o Package Density	50%	$>$ 100%
Contingency Margin	o Redundancy o Testing o Front-End Costs	0%	$\gg$ 0%

These various uncertainties related to design margin can be significantly controlled by simulation and testing of parts and procedures, in the normal course of advancing technology. It is time to start on the testing and development process now, if we are to have space construction in the near future.

The other type of uncertainty listed in Table 8.6-1 is a wild kind of variable, the contingency or accidental situation which is relatively unpredictable. Such events are partially prevented by testing of machinery and processes over many cycles, by careful training and by meticulous inspection and traceability of materials. If not preventable, the effects may be circumvented by redundancy and various alternate methods. The system analysis performed during this study has given almost no attention to such contingency possibilities. Past experience shows that additional costs are incurred by backup methods and multiple parts which reduce the likelihood of mission failure. Trade studies to evaluate the impact of such costs against the cost of additional flights to complete a given space structure need to be made as development progresses. Space construction, like construction on the ground, has an inherent set of financial and personal risks associated with it. There is much to learn about this new field of human endevor, particularly in the areas of crew performance and safety.

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9.0 CONCLUSIONS AND RECOMMENDATIONS

The foregoing analysis of construction has shown that the specific Engineering and Technology Verification Platform large space structure can be constructed in space using the Space Shuttle orbiter. The analysis was based upon a completely successful operation, without specific regard for delays or need for additional equipment, power and time for contingencies. However, it has been shown that the construction approach provides for margins in time and energy which could provide means to work around many types of contingencies. Therefore it appears that space construction, using the orbiter is both feasible and practical for structures several times larger than the orbiter.

9.1 CONSTRUCTION EQUIPMENT

The analysis showed that equipment currently being studied or under development for the Space Shuttle program can be utilized effectively as major aids to construction, if appropriate modifications are made. The major modifications required involve the RMS arm. It is recommended that this arm incorporate an upper arm roll joint and appropriate software changes. Another highly desirable modification is a tilt and pan capability for the wrist camera.

A case has been made for development of a higher pressure suit (eight-psi) and an eight-hour life support system to accomplish EVA for construction in a short time on orbit, using three crew shifts. In addition such a system eliminates the inconvenience and discomfort of prebreathing prior to EVA. It is recommended that EVA suit systems be developed specifically to support space construction, with particular emphasis on reducing prebreathing, donning time and doffing time.

Advantages have been demonstrated for the concept of a versatile construction fixture which permits access to all portions of the construction during the majority of the construction process. Such advantages include minimal power requirements for lighting and transportation, relatively small transport time requirements and capability to utilize existing manipulator equipment effectively.

It was concluded that several specialized mechanisms are desirable to enhance automation and thus minimize on-orbit time costs. It is recommended that selective development of such machinery be undertaken in preparation for future construction.

The process of analysis highlighted the need for a comprehensive series of simulations and tests to develop accurate and reliable data on time, power and crew requirements for performing typical space construction operations.

9.2 CONSTRUCTION CONCEPT IMPACT ON STRUCTURE DESIGN

The construction analysis has shown that cost effectiveness for space construction creates a profound impact on the design of the item to be constructed. This interaction is briefly summarized in Table 9.2-1. The 3-dimensional linear tri-beam structure, made of space fabricated beams was selected for the platform because of its potential for high construction productivity, its ability for growth and its legacy value in developing 3-D structures technology required for future large area space systems. Studies have shown the length of the tri-beam structure can be increased to 400 meters or more while retaining adequate loads and stiffness properties. No changes to the basic construction system or process would be required with increased length. This is a key advantage for the linear configuration. The automation afforded by space fabricated beams in conjunction with the linear shape yields the potential for high construction productivity. The main construction activity occurs as the assembled structure translates through the main fixture.

The principal dimensions of the platform were driven by several considerations. The basic tri-beam "cross sectional" dimensions, height and width, were set mainly by RMS reach limits. The resulting tri-beam spacing also facilitated the packaging of the main construction fixture. Simple swing-out rotations of key fixture members to form the basic V-shape were possible without the need for major telescoping mechanisms. Thus, RMS reach and construction fixture packaging were the drivers for the platform height/width dimensions.

The platform length was totally driven by the number of payloads and their related spacing requirements. For the advanced communications technology payloads used in the study model, provisions for 8 antenna packages with deployed diameters up to 20 meters were required.

Lap joints were utilized for joining the cross beams to the longitudinal beams because they are simpler to assemble than a butt joint. Intersection fittings that provide the joint reaction via a materials bonding arrangement were defined. Heating elements integral to the fittings provide the bonding energy.

The truss type attach ports provide the means for attaching modules and payloads, secure the SCM and thrust structure to the platform, and secure the cross beam bracing struts. The attach ports are secured to the structure by insertion into the caps of the cross beams and bonding in place similar to the lap joints.

Deployable type truss structures are provided to support the SCM and orbit transfer propulsion modules. The deployable design permits ease of installation and reduces the time for construction.

Bracing struts are utilized to minimize torque deflections on the long cross beams that support the RCS and payload modules. The primary tri-beam section is thereby minimized in dimension, making it compatible with construction from the orbiter.

Table 9.2-1. Design Drivers Summary

PLATFORM FEATURE	DESIGN DRIVER
3-D, SPACE FAB LINEAR	POTENTIAL FOR HI CONST PRODUCTIVITY CONST EASE, GOOD GROWTH POTENTIAL, MISSION ADAPTABILITY
WIDTH	RMS REACH
LENGTH	P/L COMPLEMENT (COMM TECH MISSION)
STRUCTURE	
LAP JOINT	SIMPLIFIED CONSTRUCTION
INTERSECTION FITTINGS	SIMPLIFIED JOINING
MODULE ATTACH PORTS	EASE OF INSTALLATION & SPACE SERVICING
DEPLOYABLE "FWD" & "AFT"	SIMPLIFIED CONSTRUCTION & AID STRUCTURES TECH DEV
STRUT ASSY'S	
STRUT BRACING	ALLOW SMALLER TRI-BEAM DIMENSION
P/L ALIGN VIA GROUND ADJUST	REDUCED PLATFORM COMPLEXITY
DIAGONAL CORDS	THRUST LOADS, TORSIONAL STIFFNESS
SYST CONTROL MODULE	
OPEN "T" STRUCT, EXTERNAL LRU'S	LRU ACCESS FOR SPACE SERVICING
FOLD OUT RADIATOR	ORBITER BAY PACKAGING
2-STEP S/A DEPLOYMENT	BAY PACKAGING AS A SINGLE SCM/SA UNIT
PEP TYPE S/A	UTILIZE PLANNED TECHNOLOGY DEV
ASSYMETRIC S/A CONFIG	SIMPLIFIED CONSTRUCTION (SINGLE INSTALL)
250 ELECT SYST	CONDUCTOR PACKAGING (REELS) & INSTALL EASE

The attach ports dedicated to payloads are measured to determine their deviation from zero alignment as related to the SCM reference base. The measurement is accomplished via an IMU self-contained package that measures and records the deviations. Adjustments to the payloads are made on the ground to account for the deviations. This concept simplifies the construction operation and minimizes the on orbit construction time.

Diagonal cords in all three planes of the tri-beam provide the torsional stiffness required for orbit transfer and for operational stability.

The system control module (SCM) was driven by a combination of factors. Its open "T" shape was governed by on-orbit servicing requirements. This shape provides the needed access to the individual replaceable units (LRUs) as well as ports for teleoperator berthing for remote controlled space servicing operations. In addition, the SCM was designed with fold-out radiators and an integrally packaged solar array rotary joint assembly. The entire unit was designed for transport to orbit and installation on the platform as a single package. This simplifies orbiter logistics provisions as well as the construction operations associated with its installation.

Solar arrays comprised of PEP (Power Extension Package) type wings were specified in order to utilize planned technology developments. The assymetric solar array arrangement was selected because it offers comparative simplicities in platform design and construction, inherent design and servicing advantages of consolidated subsystems at a single location, and its potential for additional payload accommodations on the open end which could provide wide unobstructed viewing. A symetric design, while offering the advantages of downsized attitude control/CMG's, does pose design complexities for integrating the OTV thrust structure with the solar array rotary joint/mounting structure.

The electrical power system voltage (250 V) was driven by construction and packaging considerations. Use of a 250 V system allows sufficient wire flexibility that wire runs can be stowed on reels for transport to orbit. This yields compact bay packaging, which is important to construction mission payload manifests which are typically volume limited. Also, wire harness installation complexity was greatly reduced by single run deployments from reels rather than the handling of a large number of individual stiff wire segments.

All of the foregoing design interactions point to the conclusion that large area systems to be constructed in space must consider the construction system/process in the design of the project. Only the proper balance between project system features and construction system complexities will produce practical system designs.

9.3 IMPACT OF SPACE CONSTRUCTION ON SHUTTLE ORBITER

The specific construction project analyzed has a potential for requiring modifications to the baseline Space Shuttle Orbiter and its associated equipment. Among the most obvious potential impacts are the modifications of the RMS to provide increased mobility (upper arm roll joint), visibility of operations (wrist camera and lights tilt and pan), and provisions to accept a cherry picker.

Provisions for additional tanks of nitrogen to support multiple EVA excursions and tanks of additional fuel for payload energy are also a major significance to orbiter systems. Mission-specific controls, displays and software must be installed for space construction. However, these may not require unusual installations as compared to other payloads.

Less obvious than the above are the implications of multiple shift crew operations. Historically, space vehicle crews have found it difficult to sleep in shifts, largely due to the noise, light and general disturbances of activity of the non-sleeping crew. This problem is also experienced to some degree by night shift workers on the earth. It is clear that the solution to the problem may require some major crew accommodations revisions, and special considerations. Examples could include additional sound proofing, vibration isolators, light - tight closures around bunks, and possibly ear plugs and eye masks for the sleepers. A mild sleeping pill is also a possibility for assisting sound sleep under the admittedly abnormal, exciting and potentially hazardous situation of space flight. The selection and detail design requirements for equipment, selection of drugs, design of crew procedures and crew training methods constitute an area of technology development in the field of habitability for space vehicles. The solutions which arise from addressing these construction-specific problems of Space Shuttle Orbiter operations can also aid other mission objectives for the orbiter and thus extend its general usefulness. The technical approaches which can be used to investigate the crew operations problems and solve them are within the current state-of-the-art. However, they do require some rather expensive simulation and measurement equipment, considerable time of expert personnel and participation of astronaut subjects in a series of experimental sessions and demonstrations, much as was done for the Apollo and Skylab projects. Since preparations for such efforts require a relatively long lead time, such studies should be started soon in order to have the required solutions in place when needed.

Another area of crew accommodations concern involves provisions to stow and gain access to additional EVA pressure garments and backpacks. If such suits are of a higher-pressure design (5-8 psi) there could be other system changes required to perform recharge and checkout operations. Such suits may require a larger stowage volume than the lower pressure garments and portable life support systems. These potential impacts need further study to evaluate approaches and quantify impacts.

APPENDIX A

ENGINEERING CONCEPT DRAWINGS

42662-45A	Engineering and Technology Verification Platform
42662-50	Tri-Beam Construction Facility System and Operations, Configuration of
42662-52	No. 2 Construction Station Applications Technology Platform
42662-53	Shuttle Bay Packing Initial Flight
42662-55	EVA Work Station
42662-56	Electric Cable Laying Machine, Crossbeam ETVP
42662-57	Control Module Axsembly - Engineering & Technology Verification Platform
42662-59	Forward Assembly and Installation
42662-60	Interorbital Thrust Structure, Engineering Technology Verification Platform
42662-61	Payload Interface Connector (Electrical) ETVP
42662-63	Structural/Mechanical Latch for Payload ETVP
42662-64	Modification to Beam Builder - ETVP
42662-65	RCS Module Installation via, Cherry Picker
42662-67	Shuttle Bay Packaging - Second Flight
42662-68	Shuttle Bay Packaging - Third Flight
42662-71	Bracing Strut Installation Via, Cherry Picker
42662-72	Male Module Attach Port
42662-74	Solar Array Assembly
42662-78	EVA Work Station Functions - Description & Illustration

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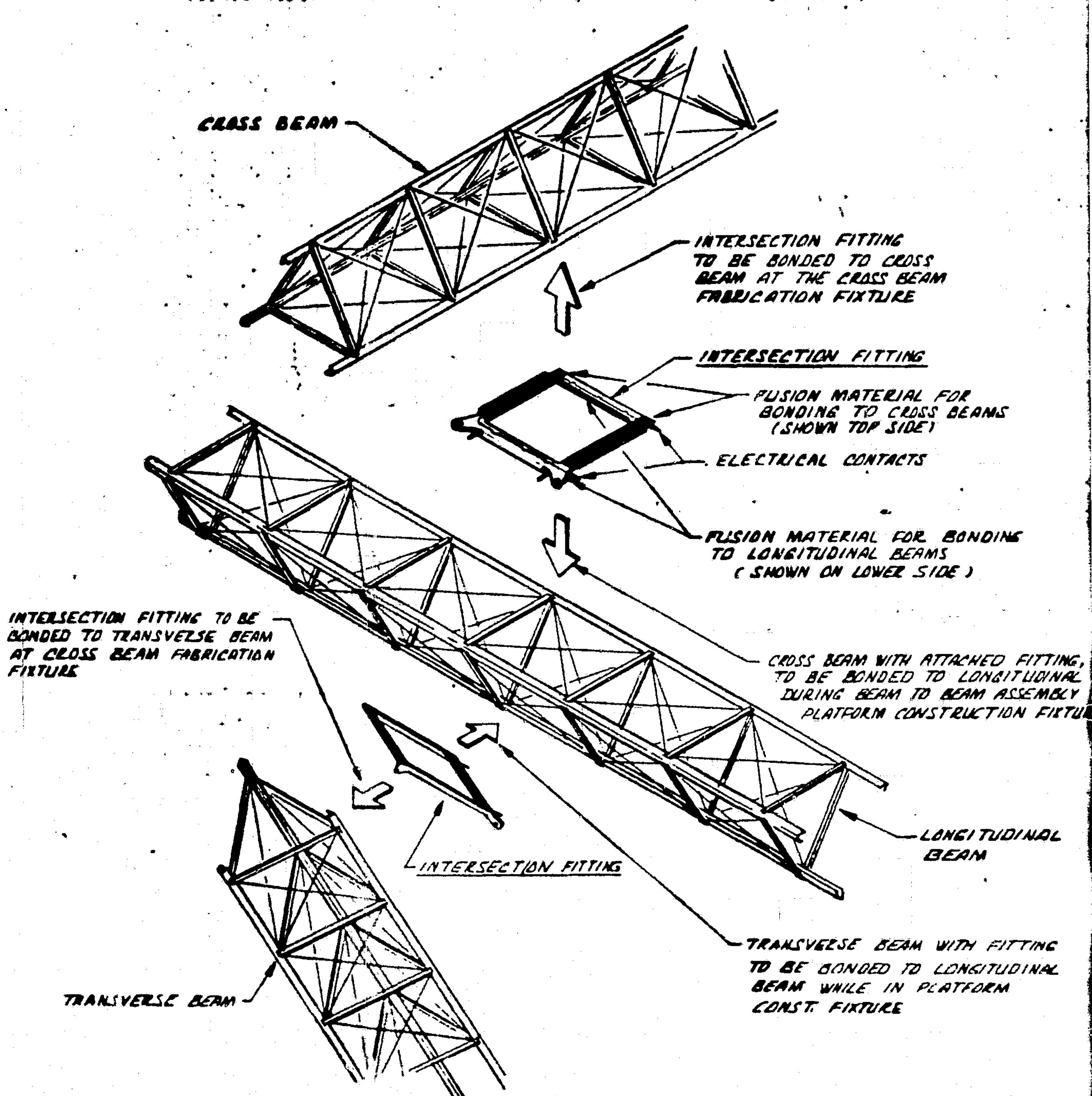

BEAM TO BEAM ATTACHMENT

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...N FITTING
...DED TO CROSS
...HE CROSS BEAM
...N FIXTURE

...ION FITTING

...N MATERIAL FOR
...ING TO CROSS BEAMS
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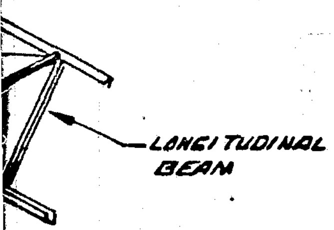
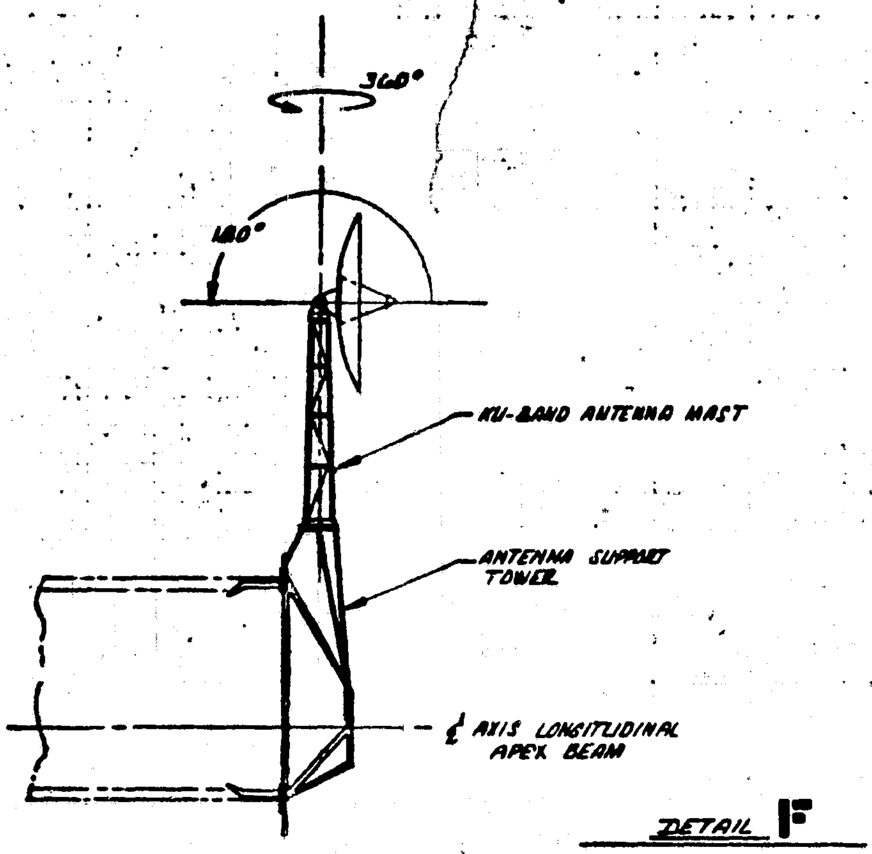
...AL CONTACTS

...ATERIAL FOR BONDING
...TUDINAL BEAMS
... ON LOWER SIDE)

...S BEAM WITH ATTACHED FITTING,
... BE BONDED TO LONGITUDINAL BEAM
...RING BEAM TO BEAM ASSEMBLY IN THE
...PLATFORM CONSTRUCTION FIXTURE



...VERSE BEAM WITH FITTING
... BONDED TO LONGITUDINAL
... WHILE IN PLATFORM
... FIXTURE



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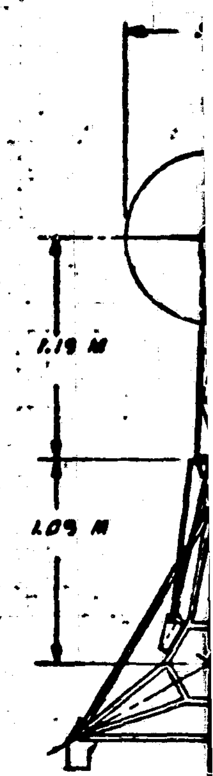

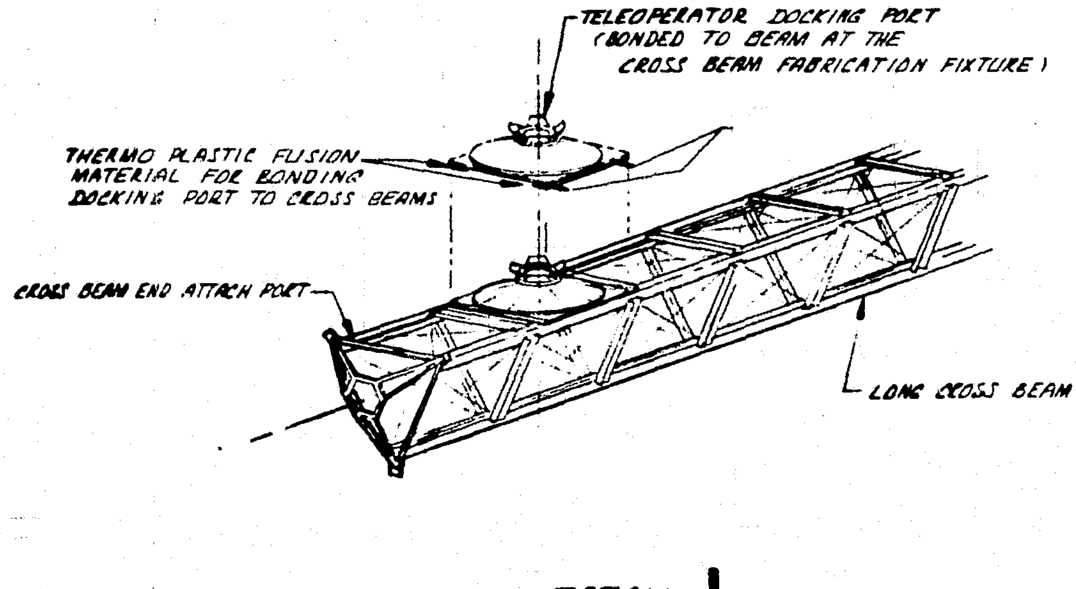

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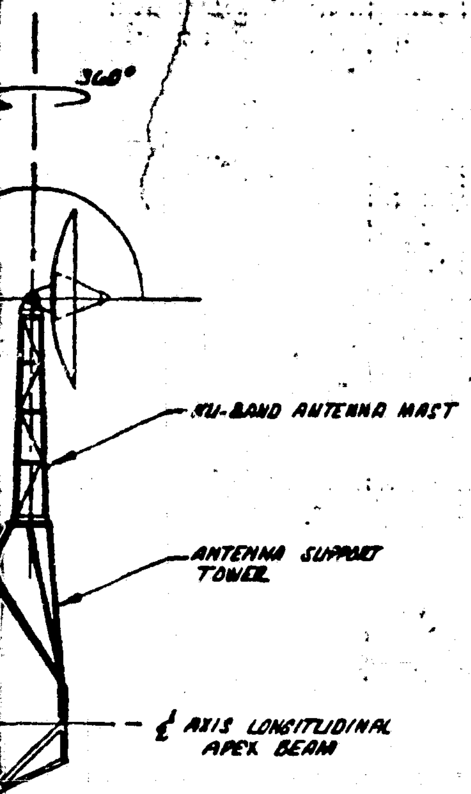

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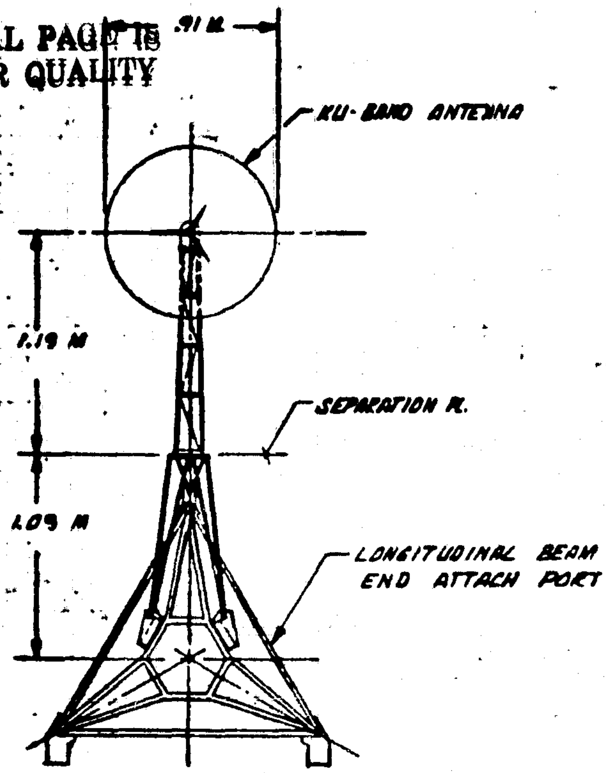

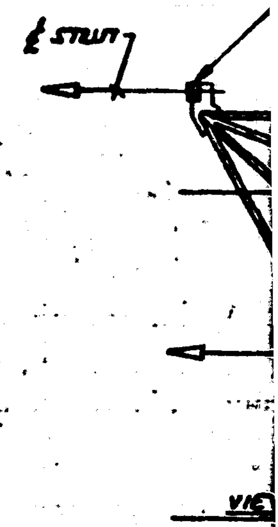

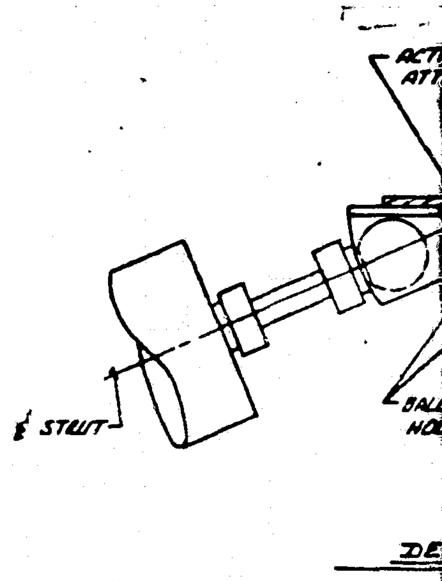

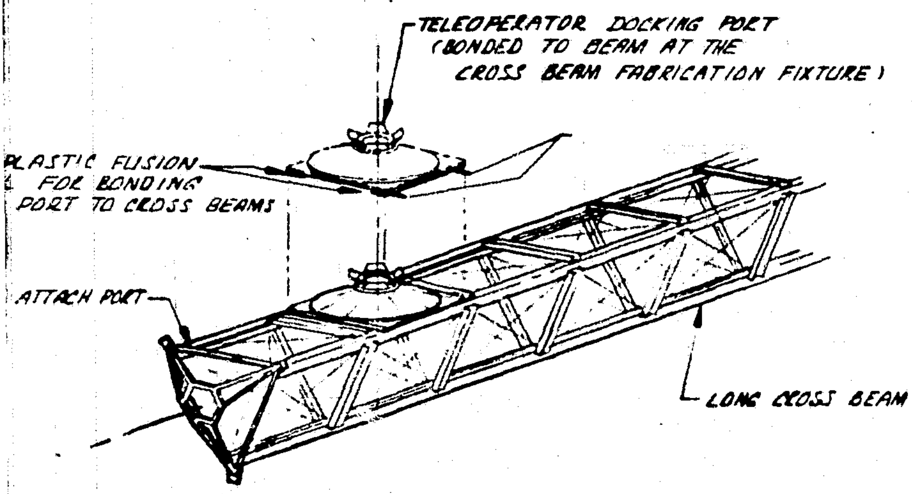

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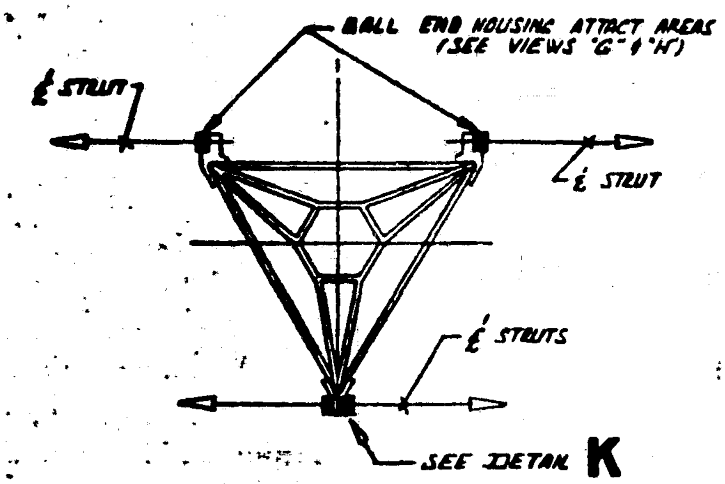
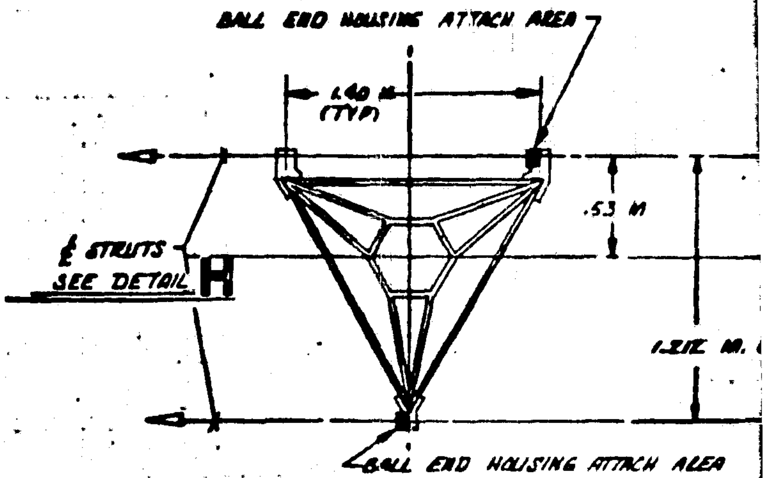


VIEW J - J



LONG CROSS BEAM ACTIVE PORT

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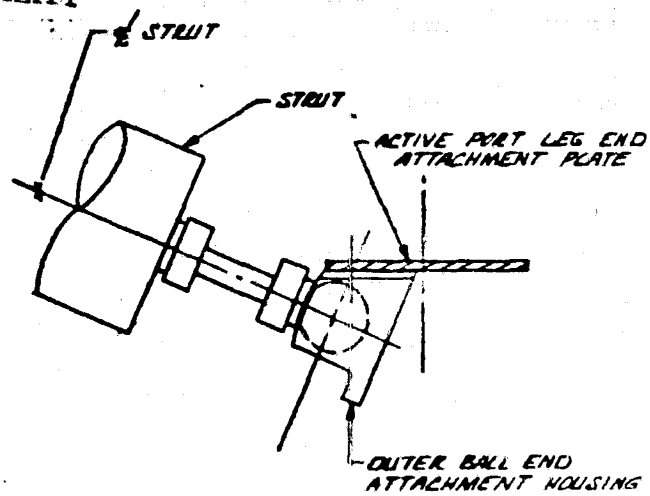

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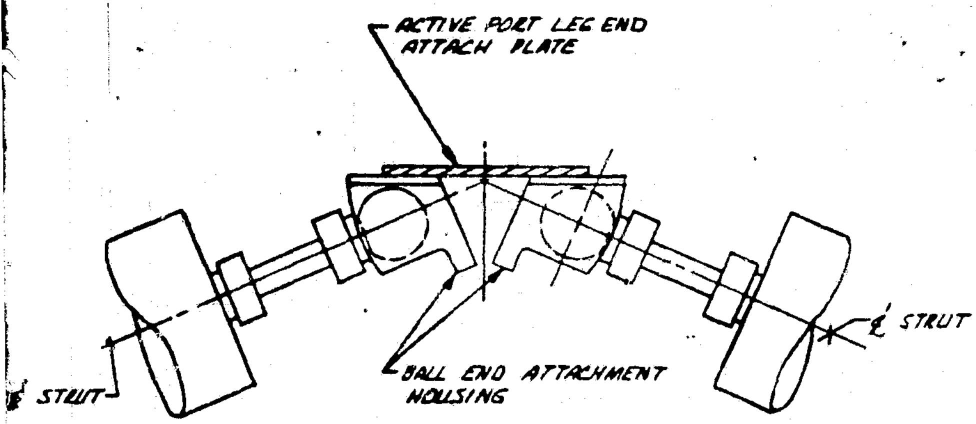

DETAIL K

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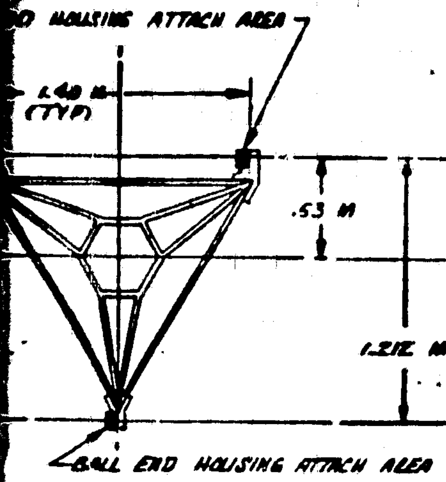
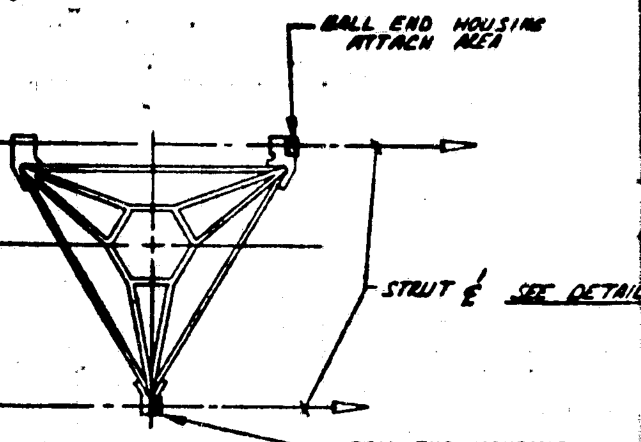


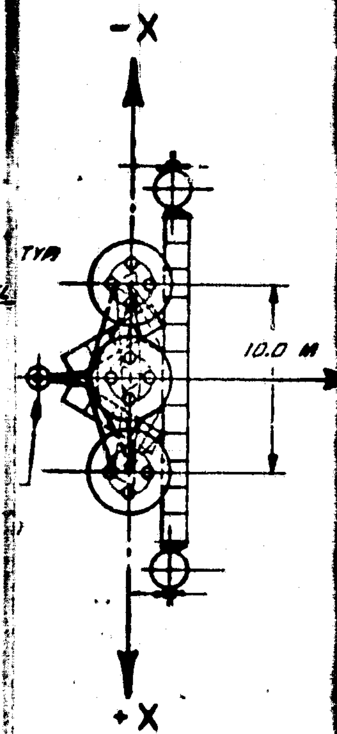
C CROSS BEAM ACTIVE PORT

VIEW D - D



SHORT CROSS BEAM ACTIVE PORT

VIEW E - E



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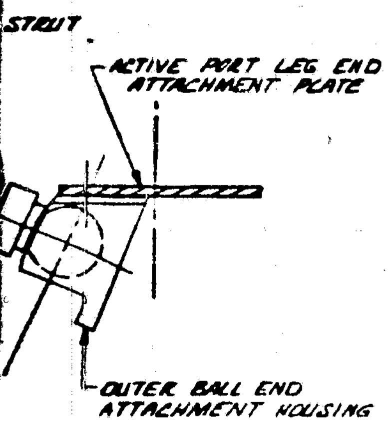
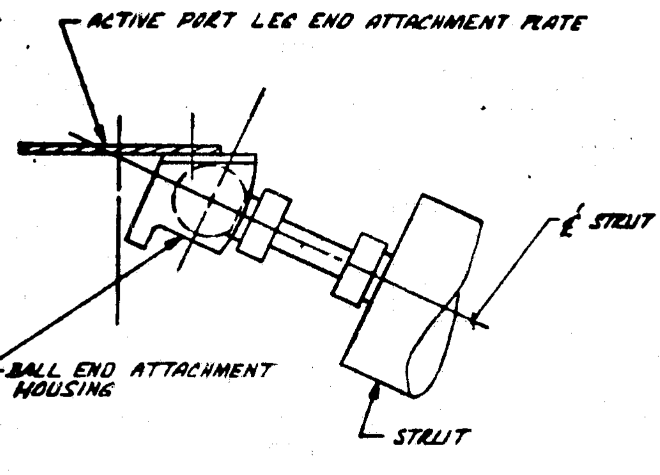
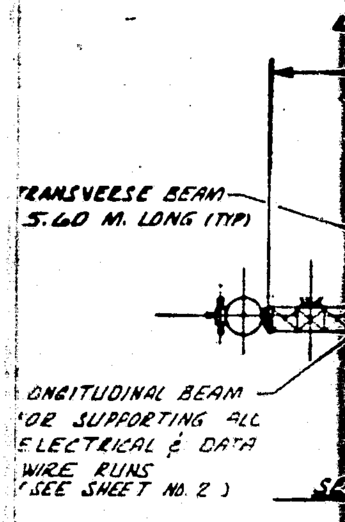


DETAIL H

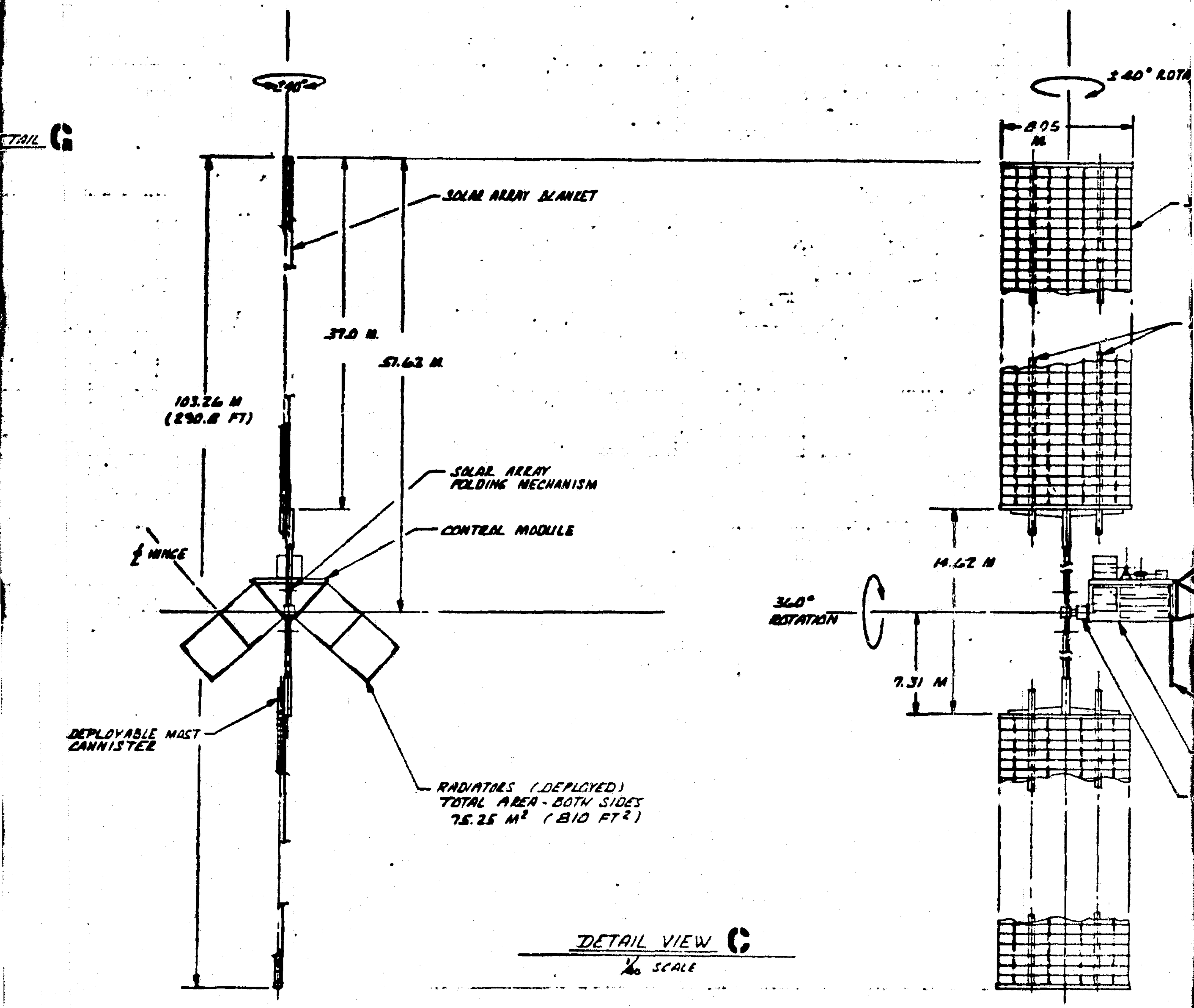


DETAIL G



FOLDOUT FRAME

13 12 11 10

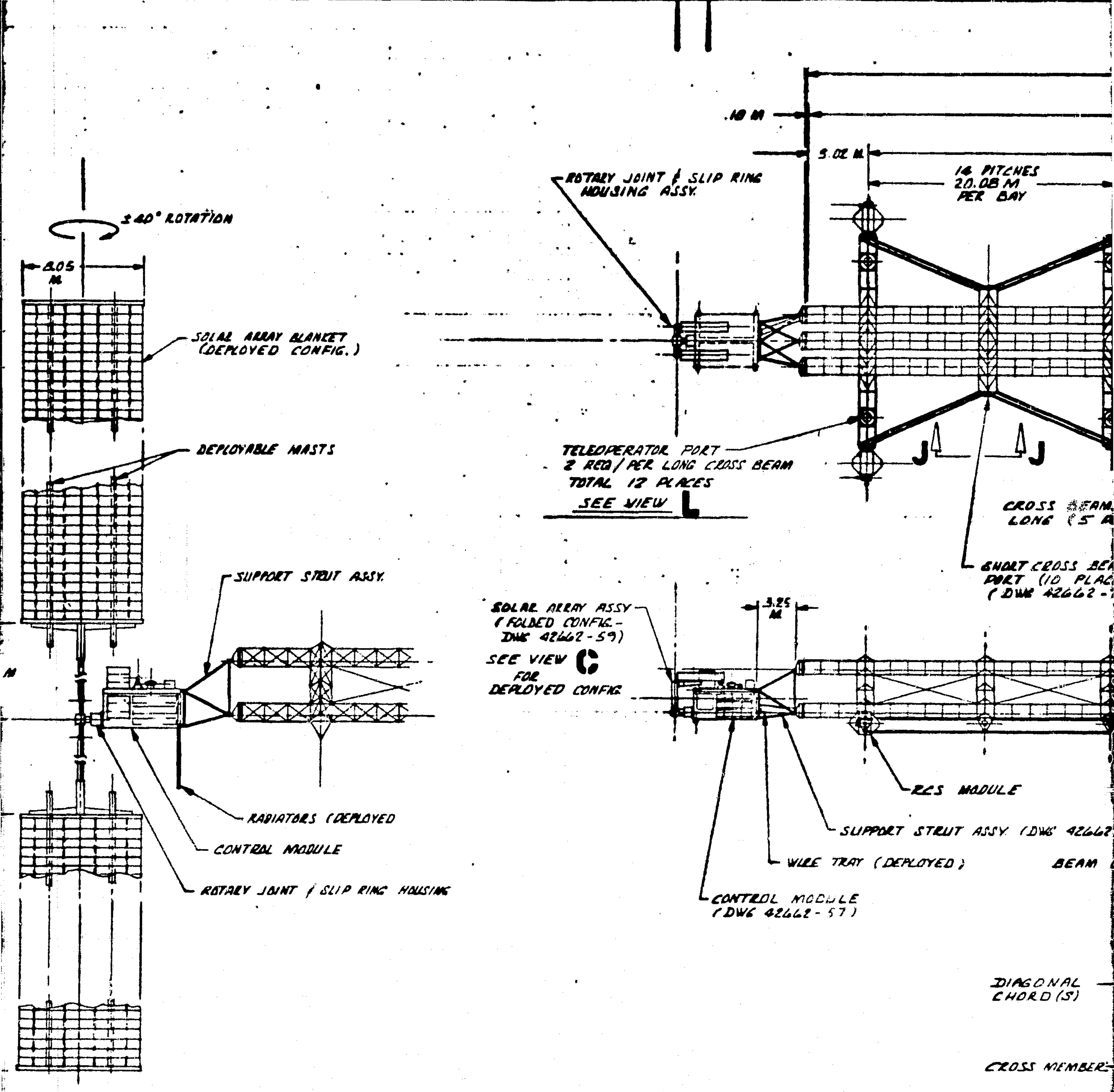


DETAIL VIEW C

1 FOLDOUT FRAME

13 12 11 10

10 9 8

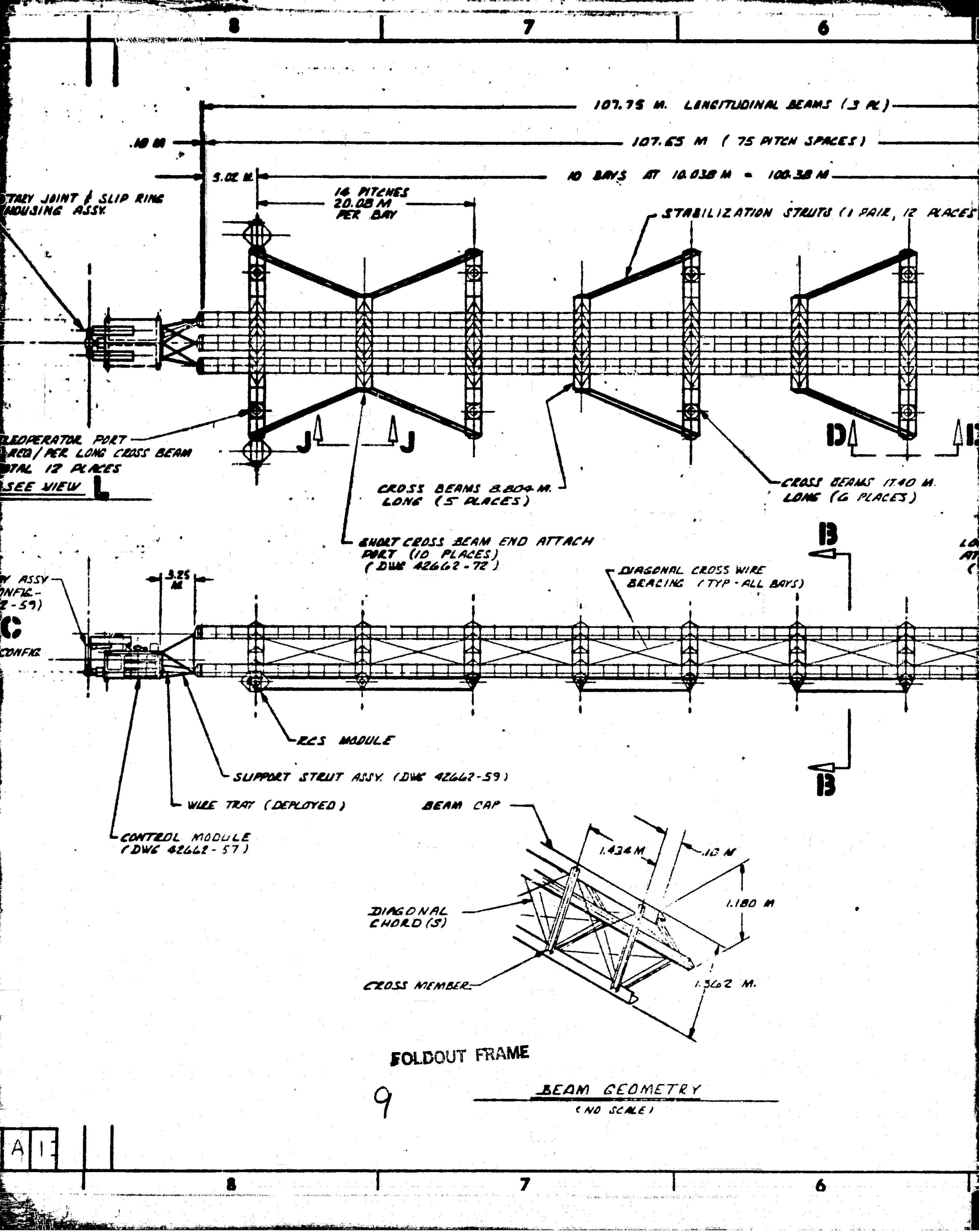


FOLDOUT FRAME

8

42662-45 A 1

10 9 8

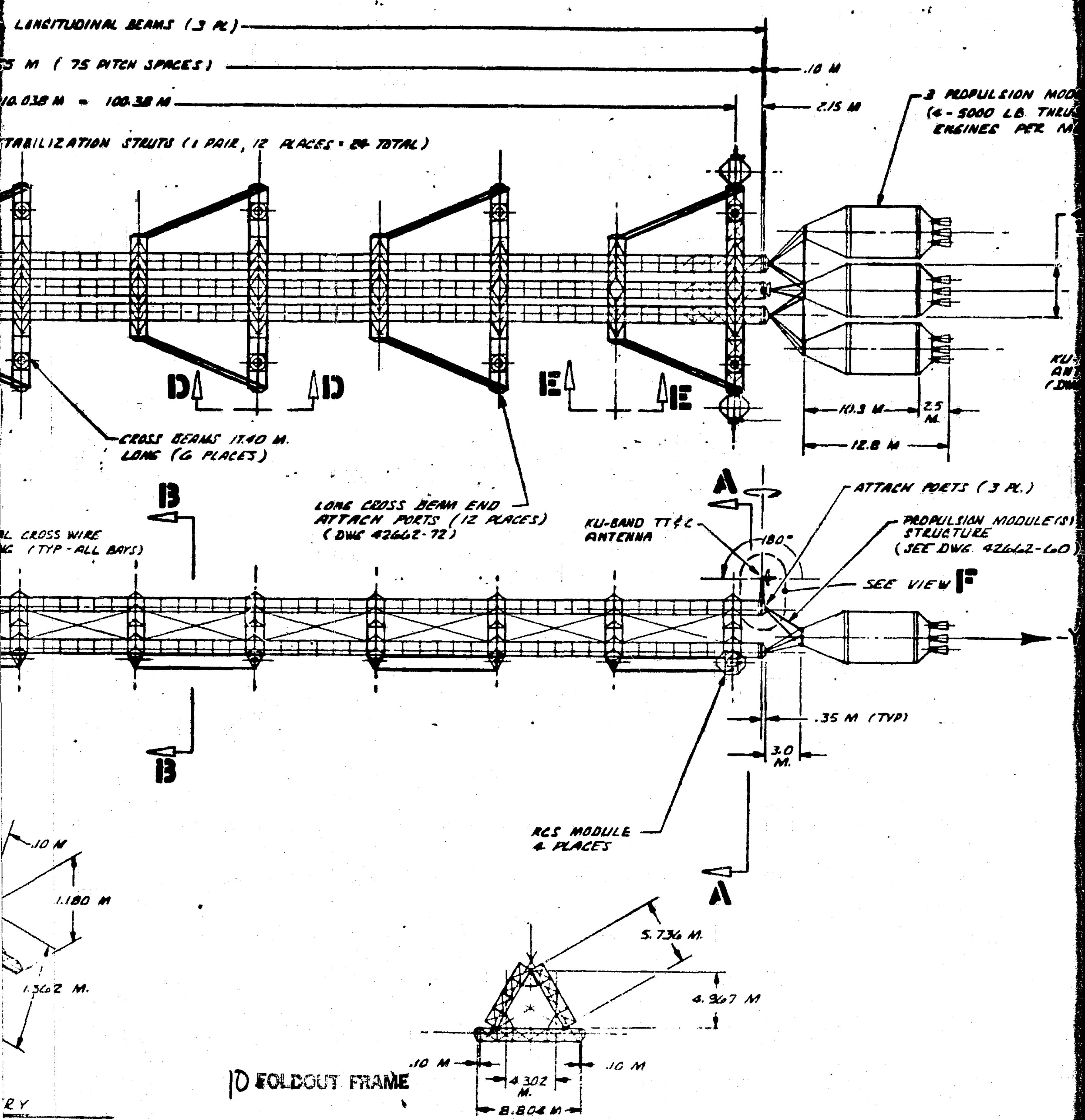


FOLDOUT FRAME

9

BEAM GEOMETRY
(NO SCALE)

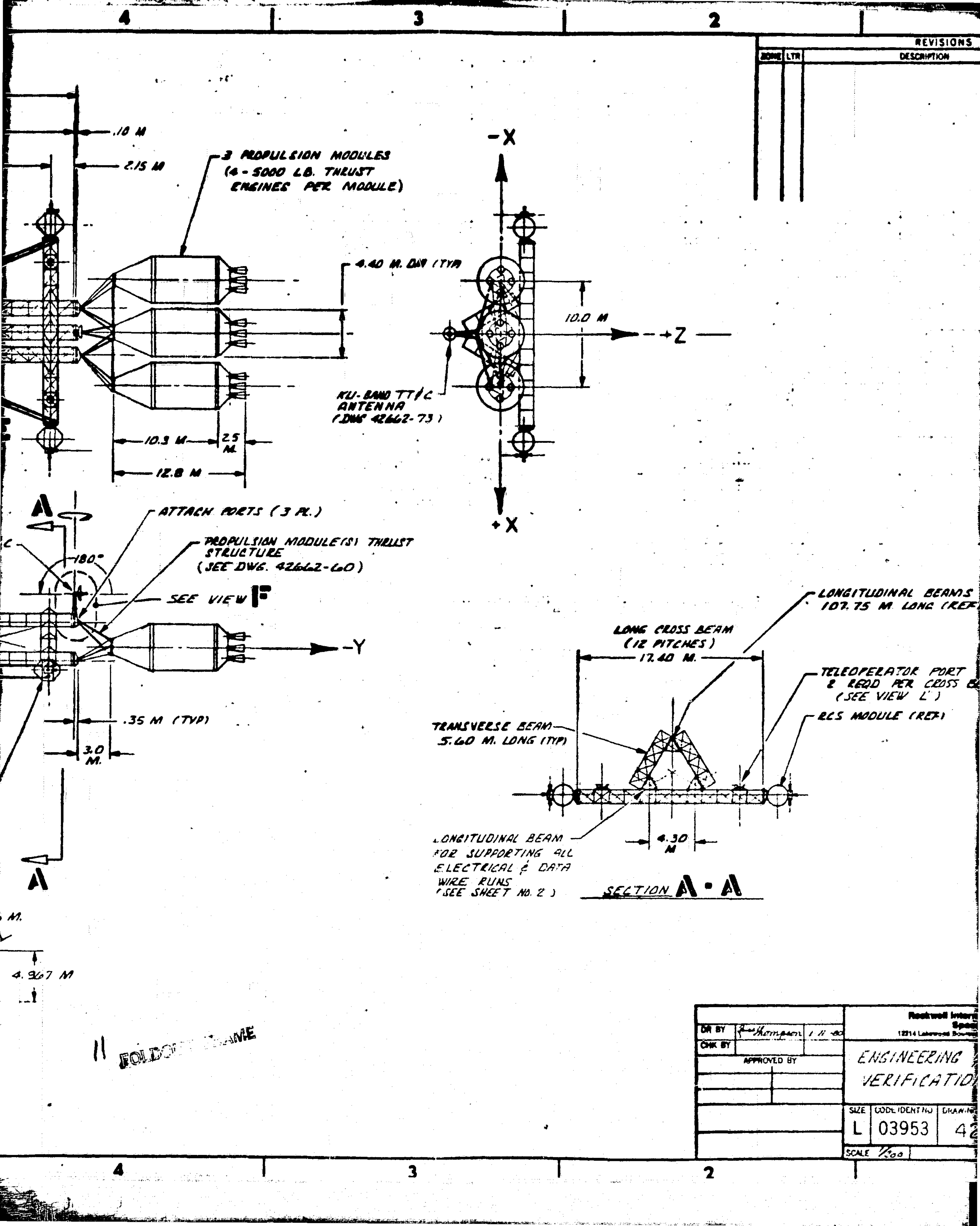
6 5 4



FOLDOUT FRAME

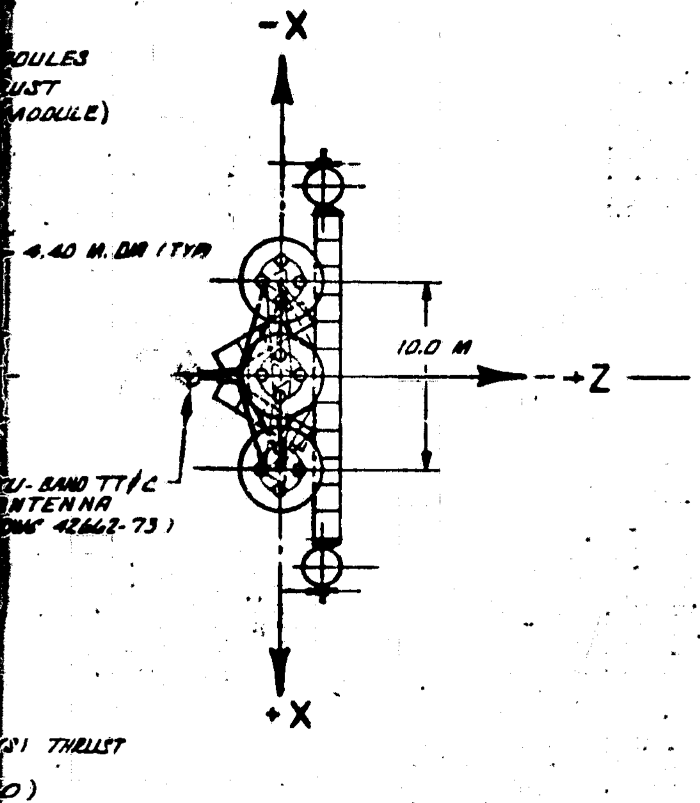
SECTION B - B

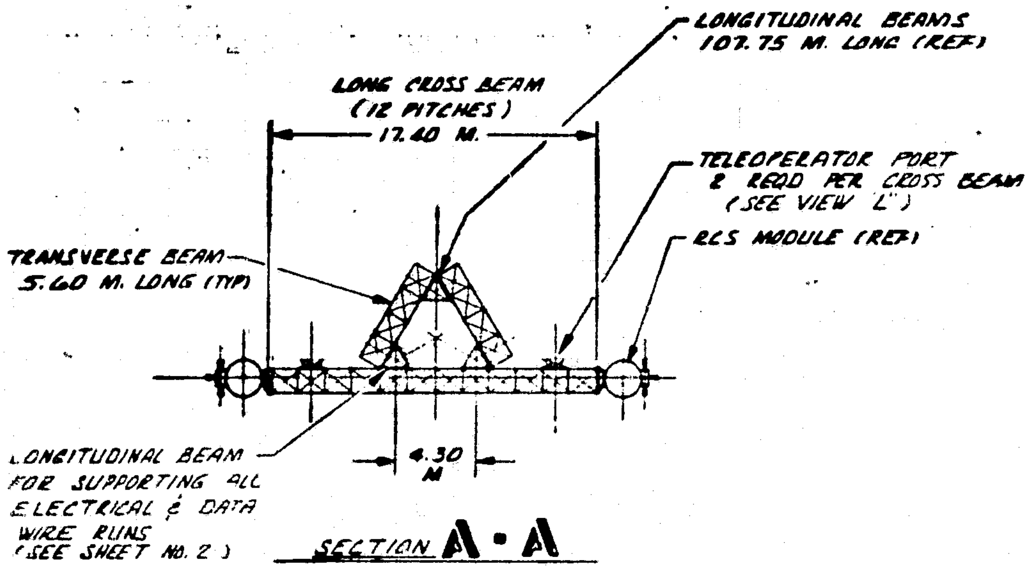
6 5 4



REVISIONS
ZONE
LTR
DESCRIPTION
.10 M
2.15 M
3 PROPULSION MODULES (4 - 5000 LB. THRUST ENGINES PER MODULE)
-X
4.40 M. DIA (TYP)
10.0 M
+Z
KU-BAND TT/C ANTENNA (DWG 42662-73)
10.3 M
2.5 M.
12.8 M
+X
A
ATTACH PORTS (3 PL.)
PROPULSION MODULE(S) THRUST STRUCTURE (SEE DWG. 42662-60)
180°
SEE VIEW F
-Y
.35 M (TYP)
3.0 M.
A
LONGITUDINAL BEAMS 107.75 M. LONG (REF)
LONG CROSS BEAM (12 PITCHES)
17.40 M.
TELEOPERATOR PORT 2 REQD PER CROSS B
(SEE VIEW L)
RCS MODULE (REF)
TRANSVERSE BEAM 5.60 M. LONG (TYP)
LONGITUDINAL BEAM FOR SUPPORTING ALL ELECTRICAL & DATA WIRE RUNS (SEE SHEET NO. 2)
4.30 M
SECTION A - A
M.
4.967 M
FOLDOUT FRAME
DR BY
CHK BY
APPROVED BY
Rockwell Intern
12214 Lakewood Boul
ENGINEERING
VERIFICATIO
SIZE
CODE IDENT NO
DRAWING
L
03953
4
SCALE 1/200
4
3
2

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED





SECTION A-A

A-1,
A-2

DR BY Thompson 1 11 80	Rockwell International Corporation Space Division 12214 Lakewood Boulevard Downey California 90241
CHK BY	ENGINEERING & TECHNOLOGY VERIFICATION PLATFORM
APPROVED BY	SIZE L · CODE IDENT NO 03953 · DRAWING NO 42662-45A
	SCALE 1/200 · SHEET

42662-45A

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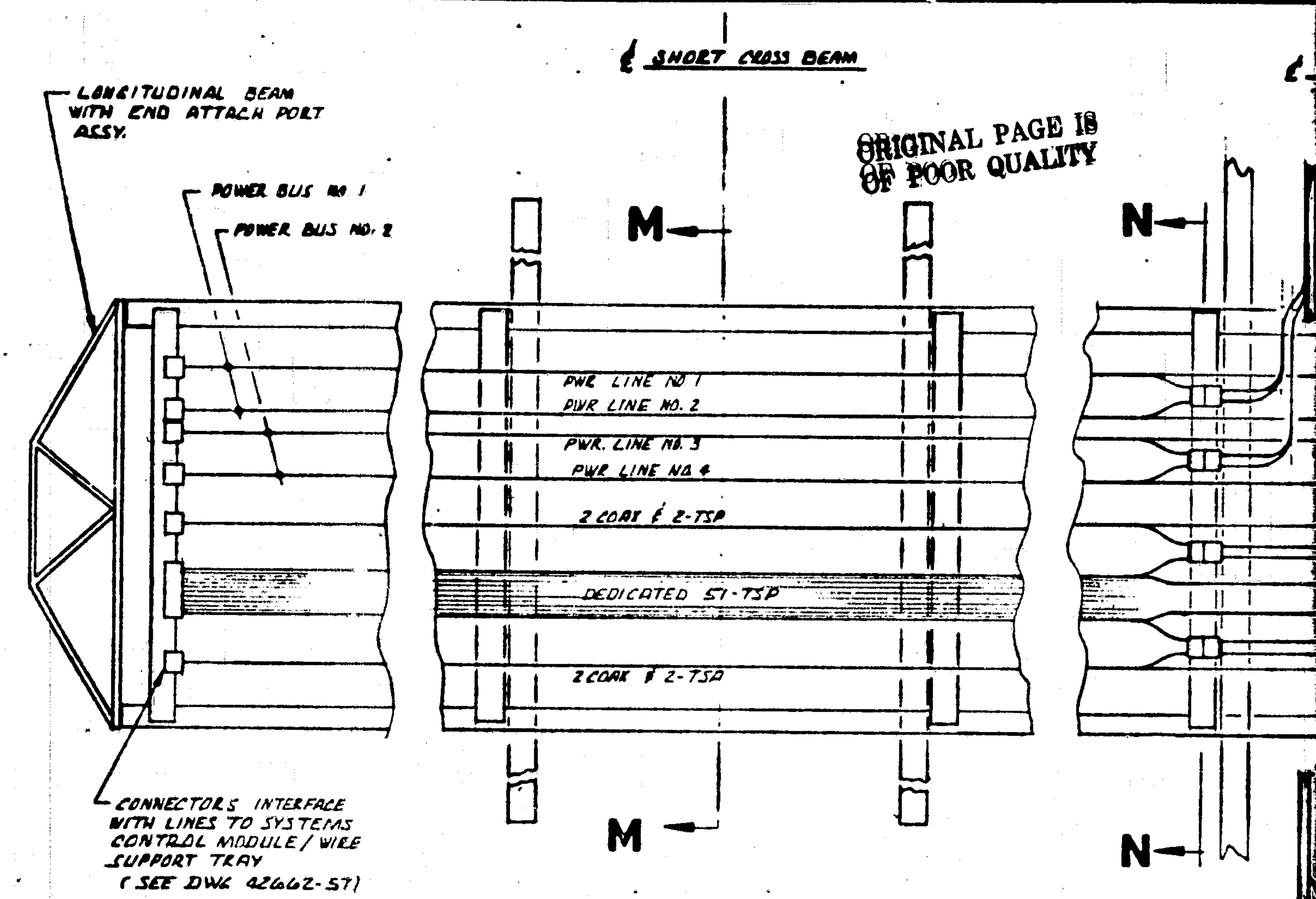

FOLDOUT FRAME

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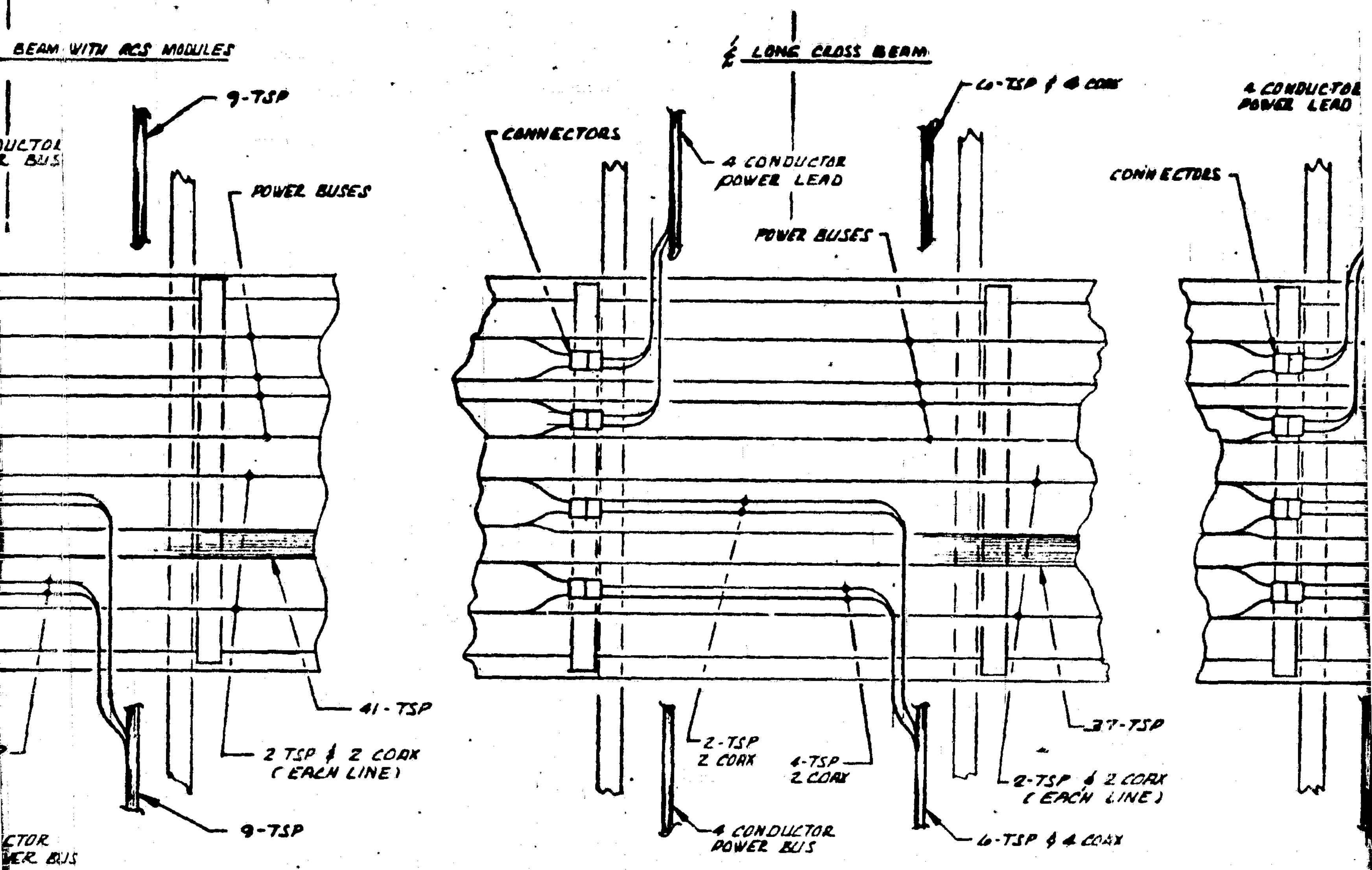

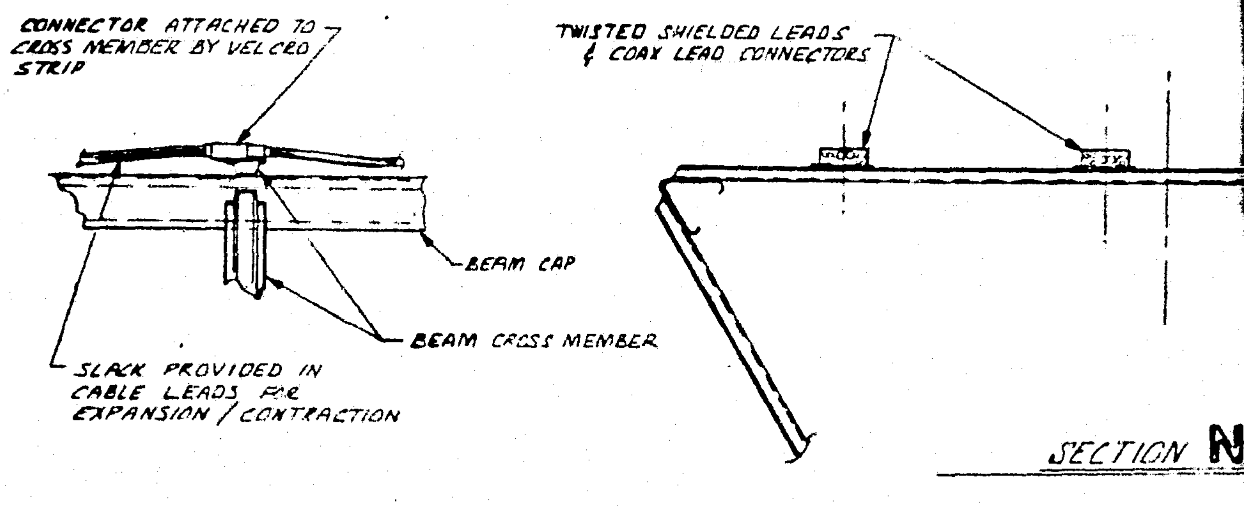

FOLDOUT FRAME 2

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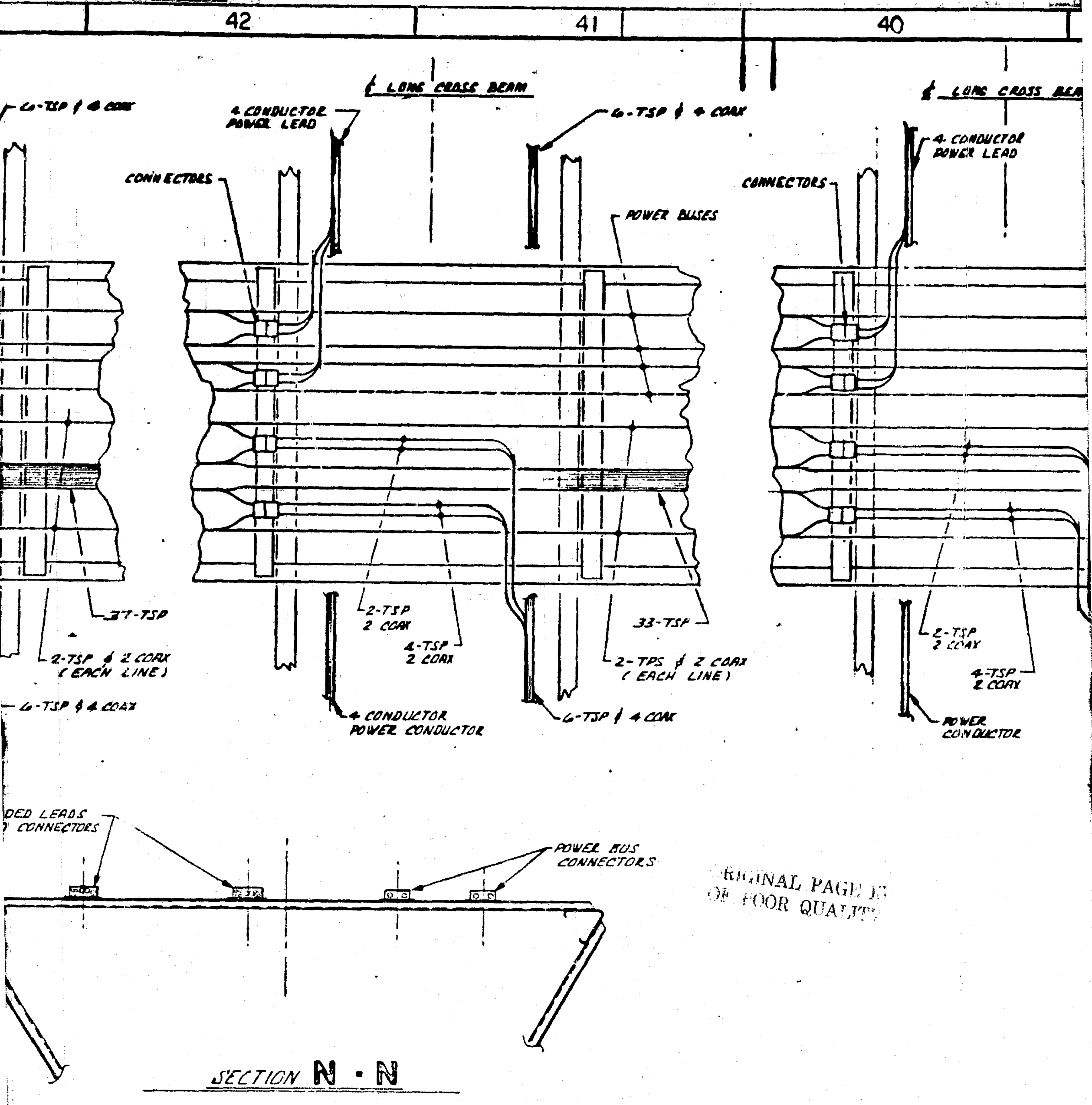

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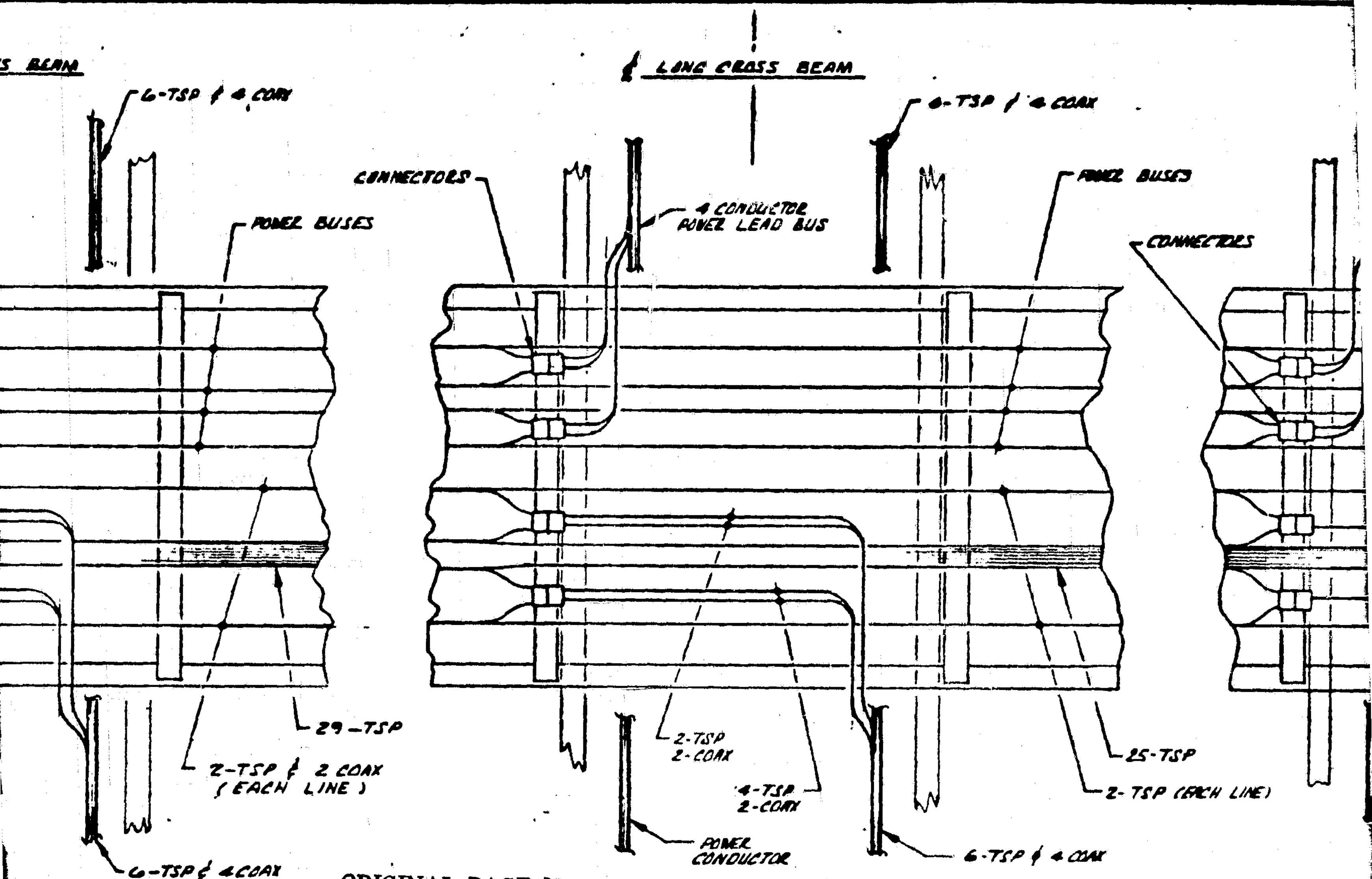
3 FOLDOUT FRAME

42662 45	A	2

42 41 40



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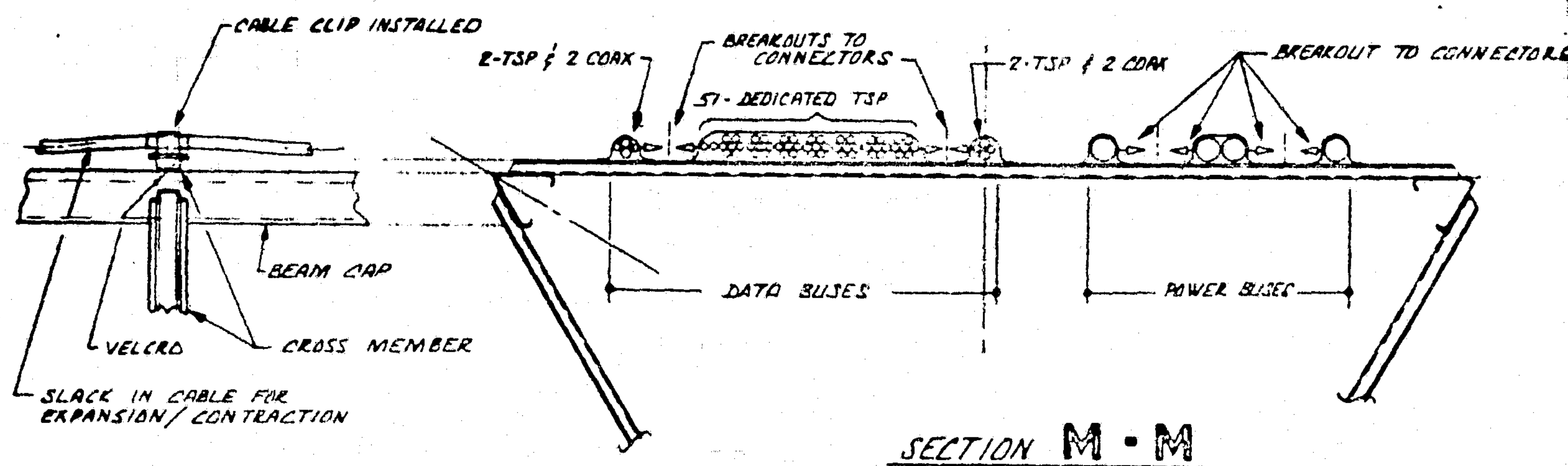
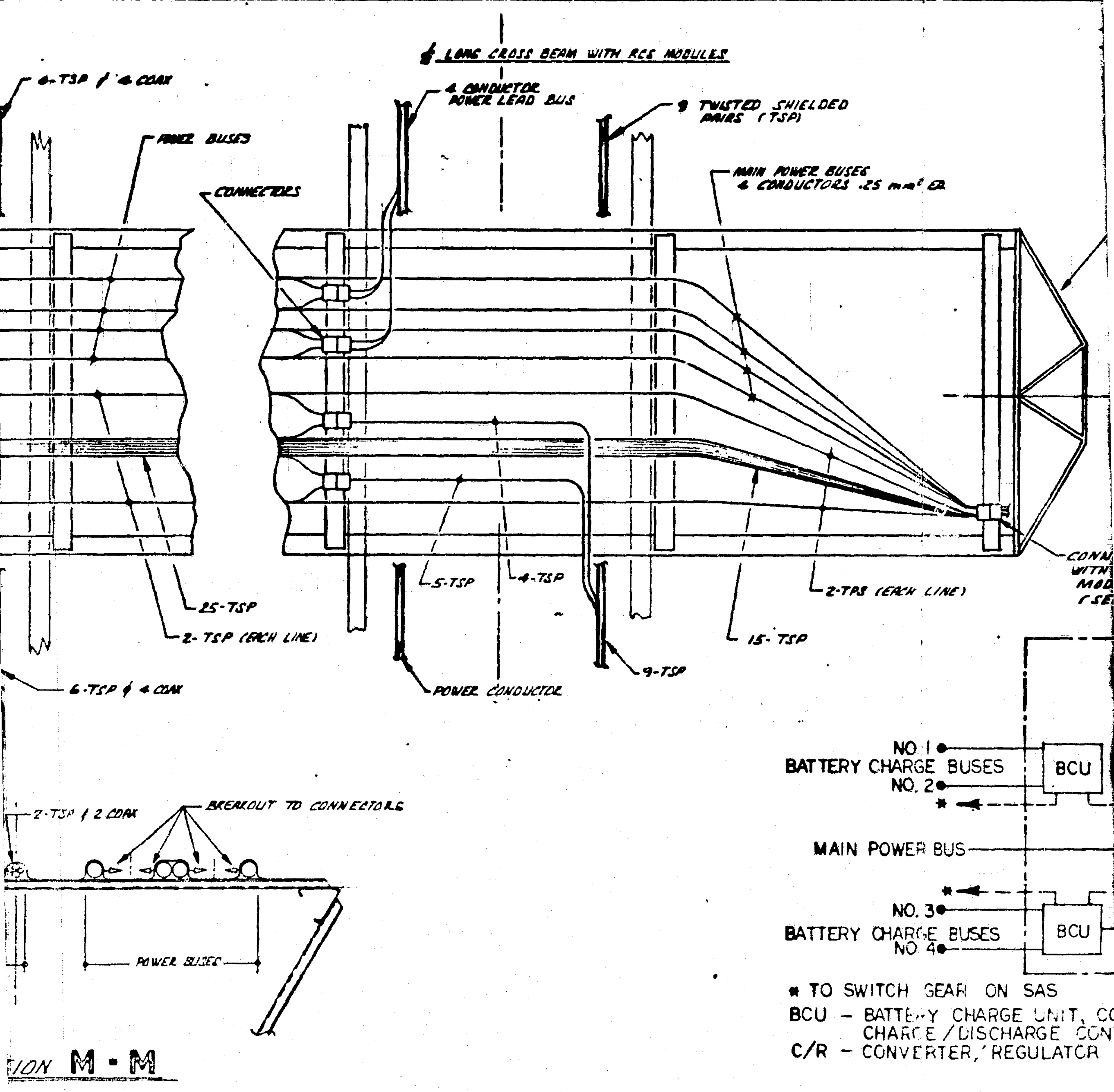
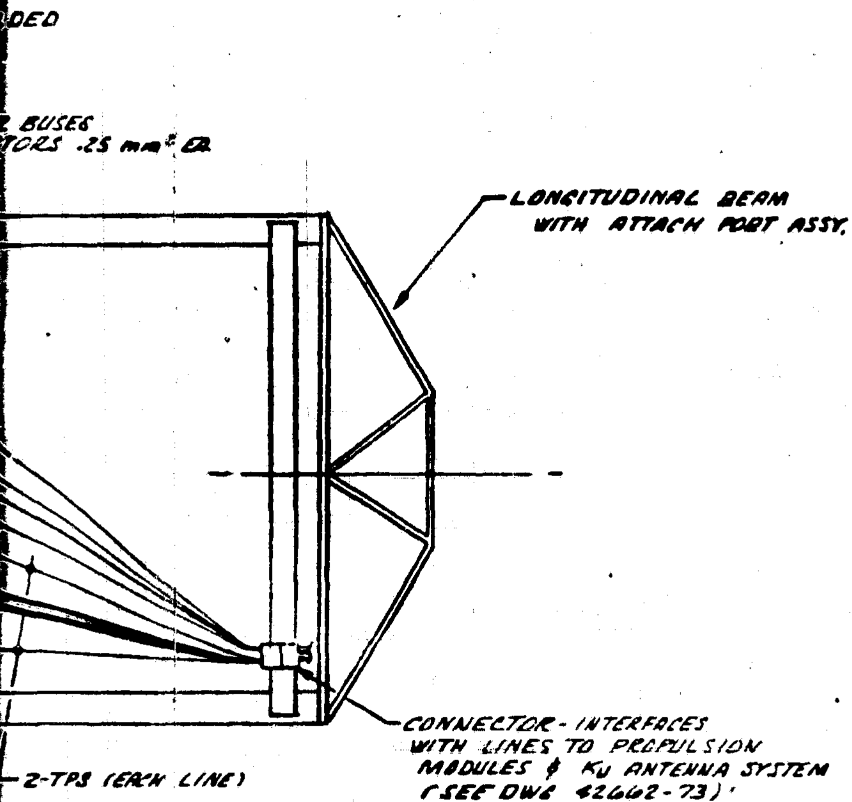


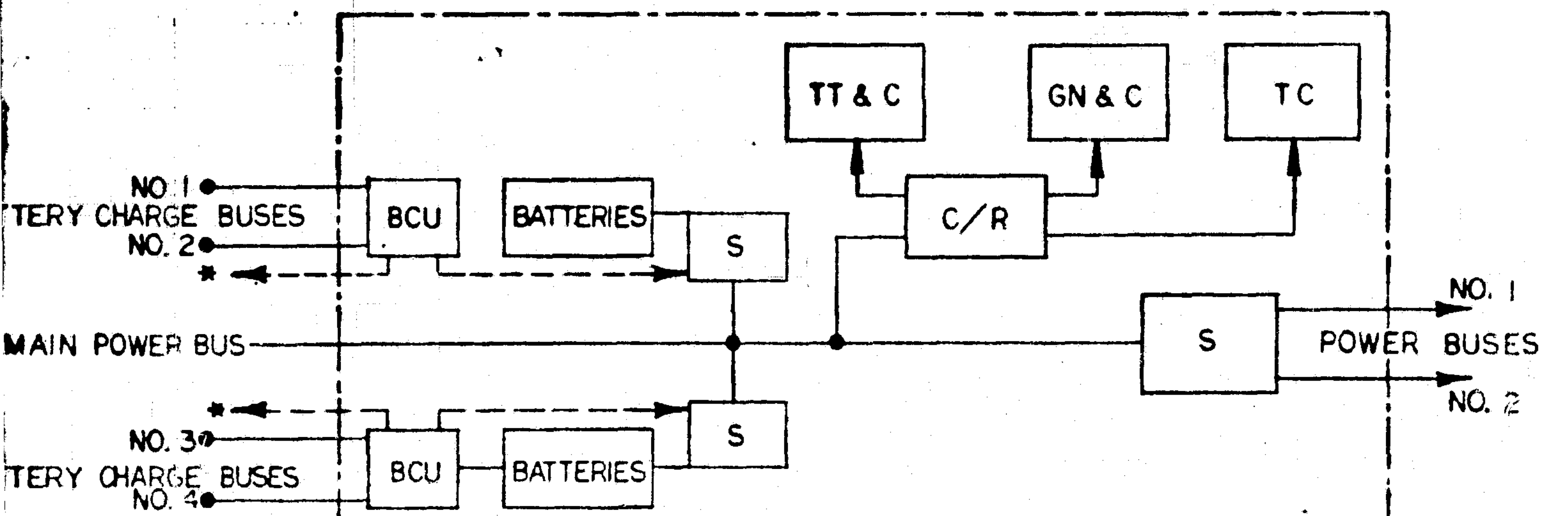
SECTION M-M

4 FOLDOUT FRAME



5 FOLDOUT FRAME





TO SWITCH GEAR ON SAS
U – BATTERY CHARGE UNIT, CONTAINS CHARGE/DISCHARGE CONTROLLER
R – CONVERTER/REGULATOR

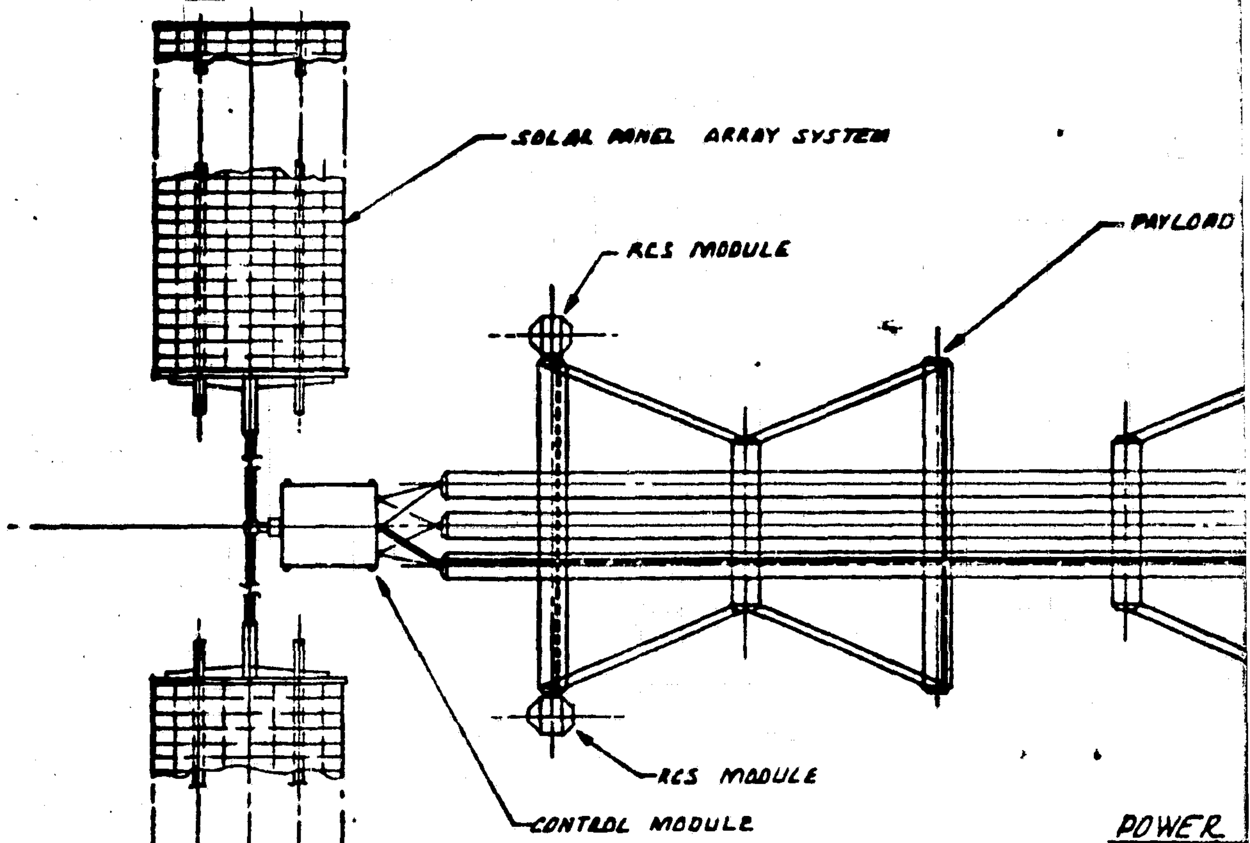
TT & C – TRACKING, TELEMETRY & COMMAND SUBSYSTEM
S – SWITCH GEAR

GN & C – GUIDANCE, NAVIGA[TION] & CONTROL SYS[TEM]
TC – THERMAL CONTRO[L] SYSTEM

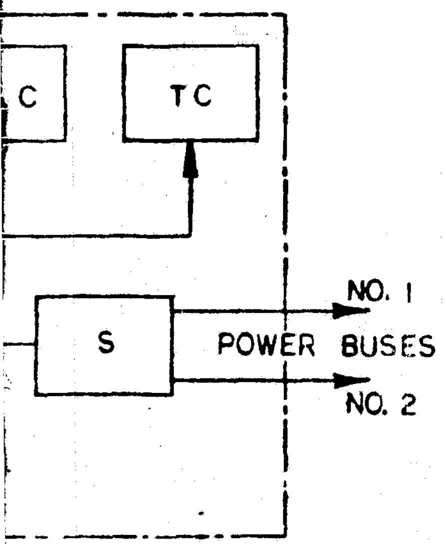
CONTROL MODULE ELECTRICAL POWER SYSTEM

6 FOLDOUT FRAME

42662-45	A	2



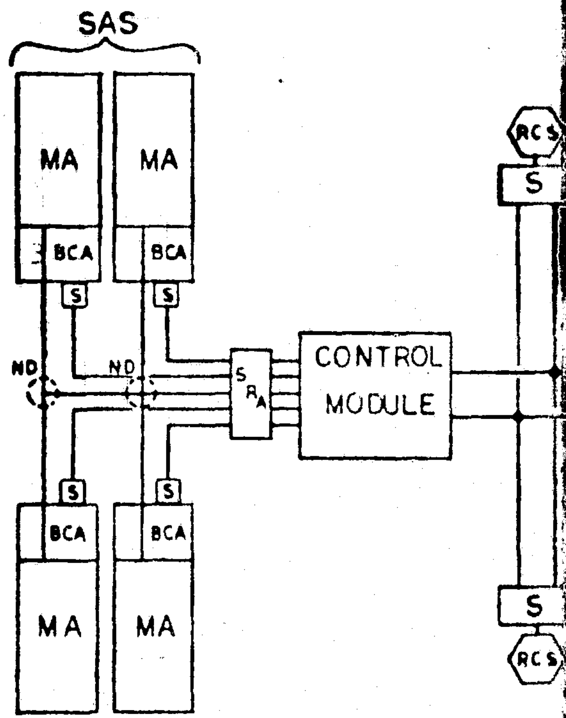
POWER
(E



EMETRY &
SYSTEM

GN & C - GUIDANCE, NAVIGATION
& CONTROL SYSTEM
TC - THERMAL CONTROL
SYSTEM

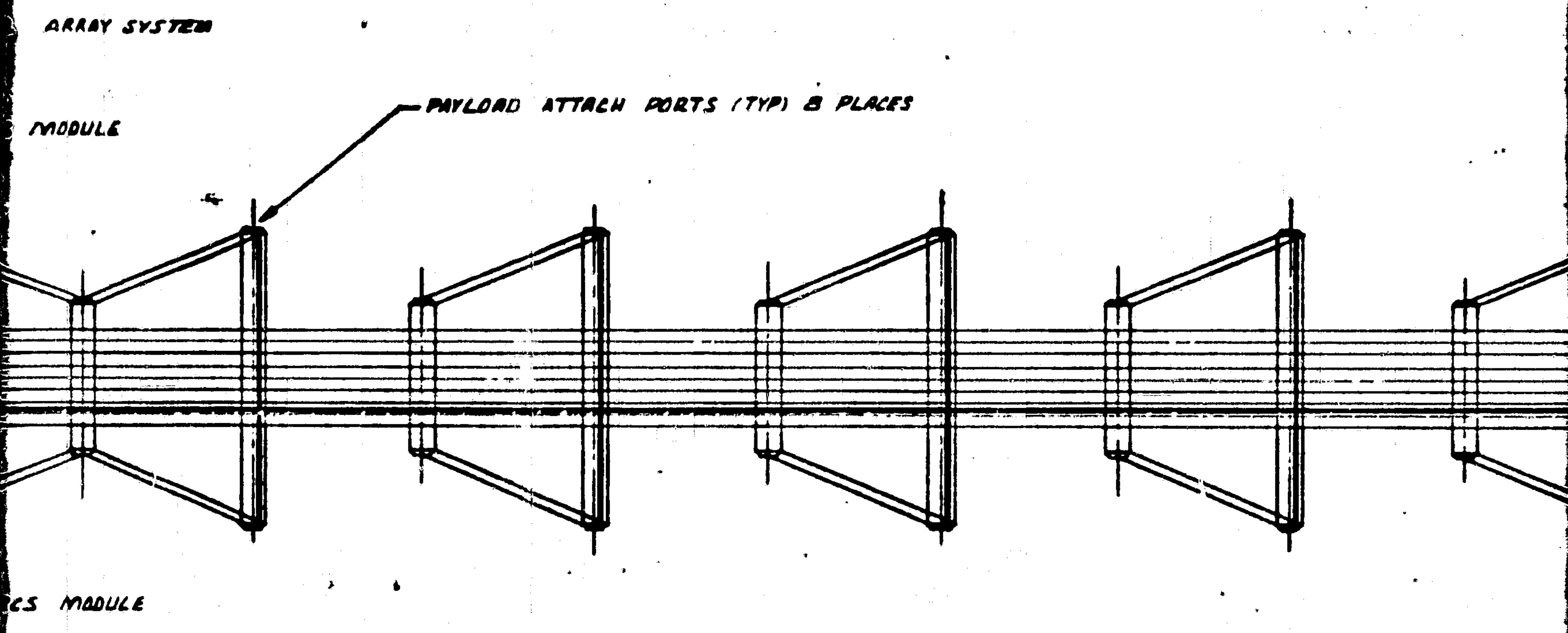
SYSTEM



ELE

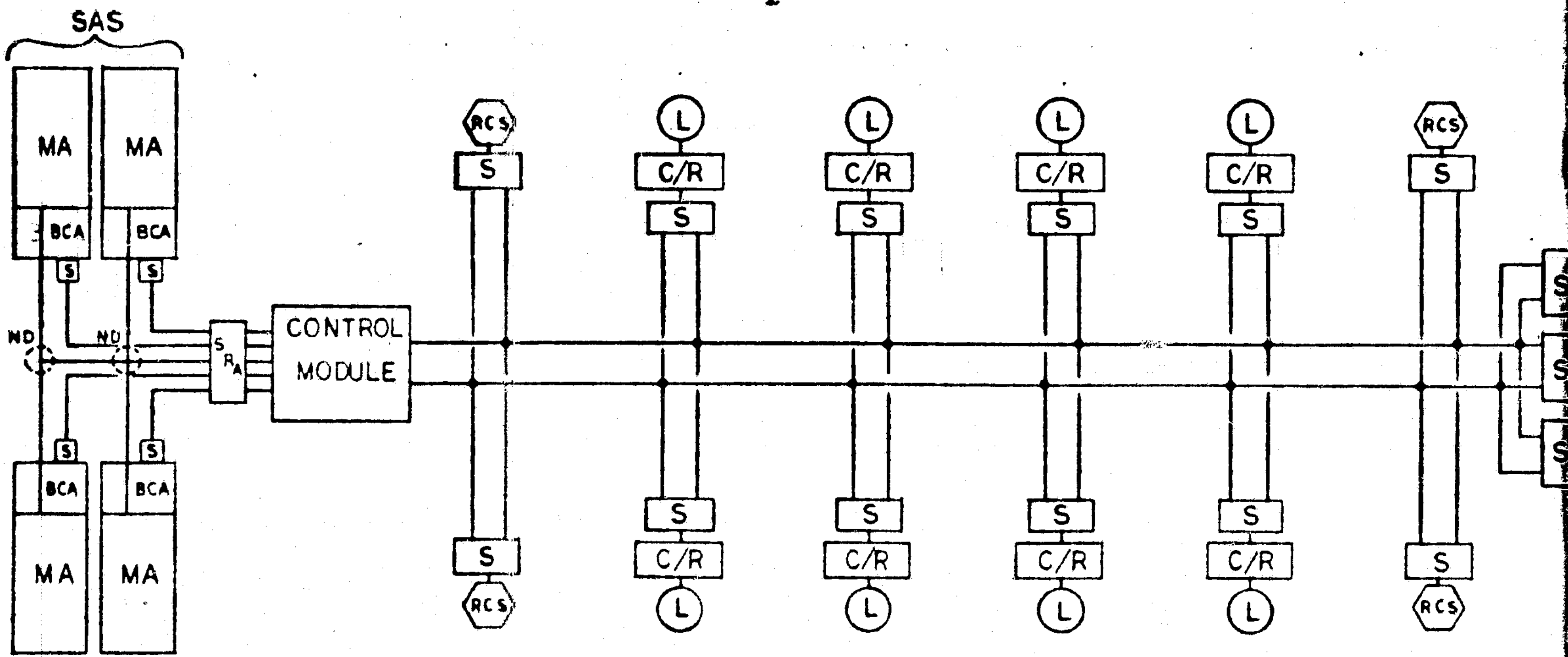
7 FOLDOUT FRAME

A 2



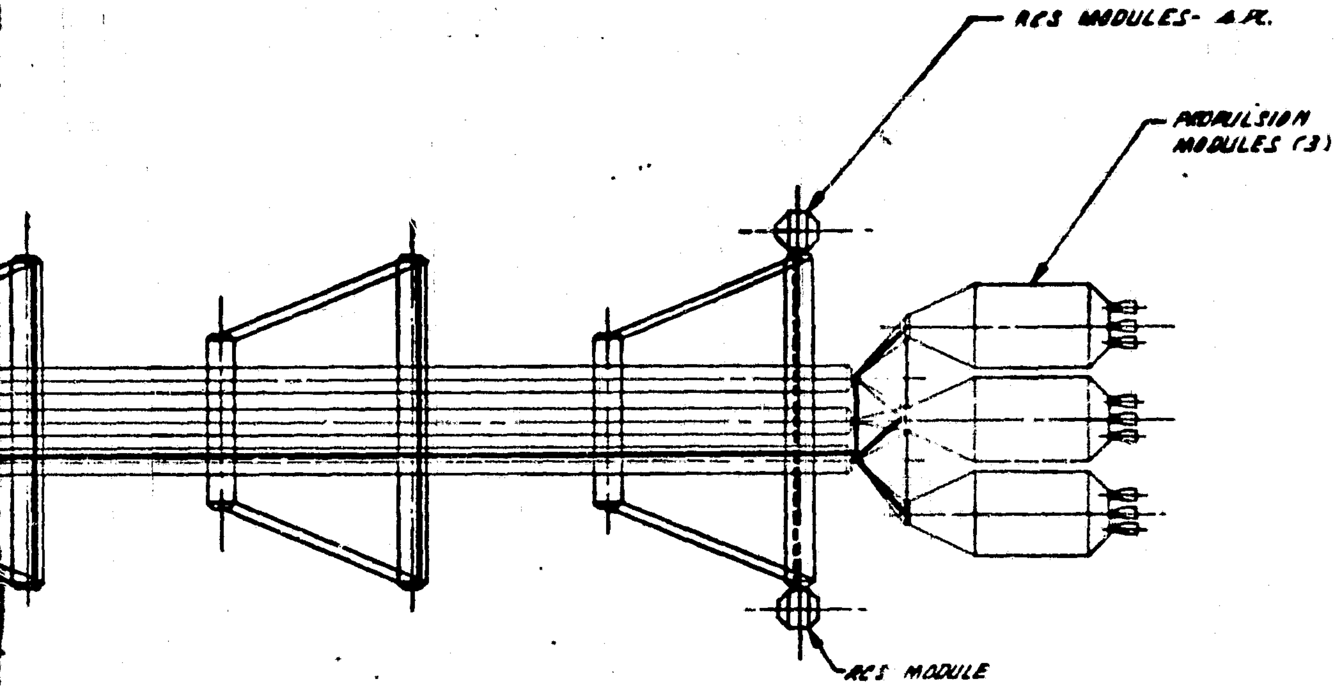
POWER & DATA LINE ROUTING ARRANGEMENT

(ENGINEERING & TECHNOLOGY VERIFICATION PLATFORM)

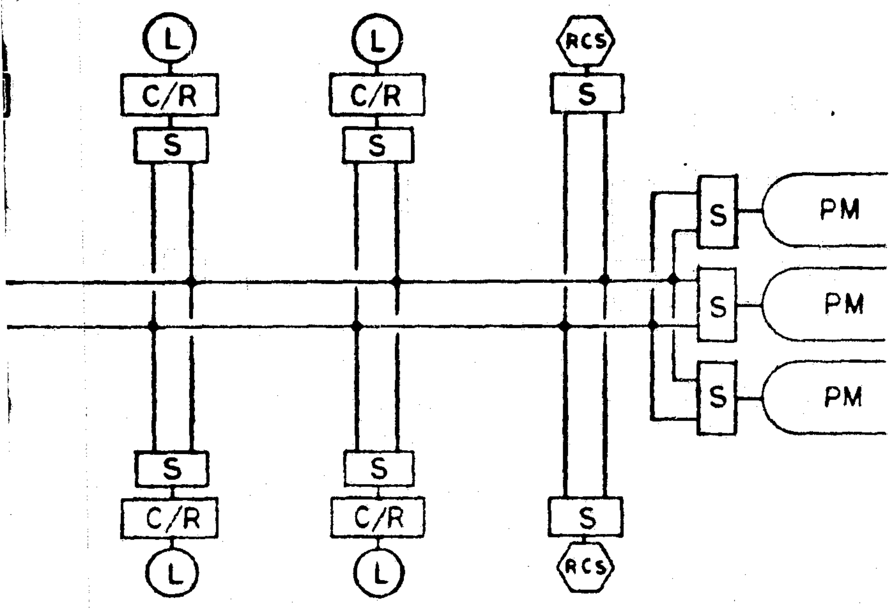


ELECTRICAL POWER FUNCTIONAL SCHEMATIC

8 FOLDOUT FRAME



ARRANGEMENT
FICATION PLATFORM)



SAS - SOLAR ARRAY SYSTEM
MA - MAIN ARRAY
BCA - BATTERY CHARGE ARRAY
ND - NODDING DRIVE
SRA - SLIP RING ASSEMBLY
S - SWITCH GEAR
RCS - REACTION CONTROL SYSTEM
C/R - CONVERTER / REGULATOR
L - LOAD
PM - PROPULSION MODULE

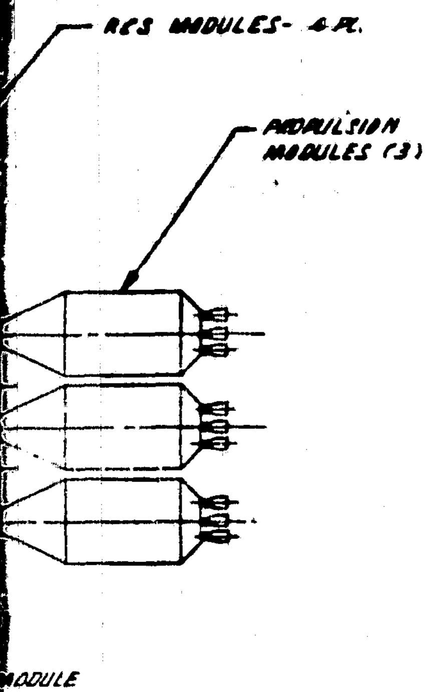
IAL SCHEMATIC

9 FOLDOUT FRAME

SIZE L
SCALE

26 | 25

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



D

C

SAS - SOLAR ARRAY SYSTEM
MA - MAIN ARRAY
BCA - BATTERY CHARGE ARRAY
ND - NODDING DRIVE
SRA - SLIP RING ASSEMBLY
S - SWITCH GEAR
RCS - REACTION CONTROL SYSTEM
C/R - CONVERTER/REGULATOR
L - LOAD
PM - PROPULSION MODULE

B

10 FOLDOUT FRAME

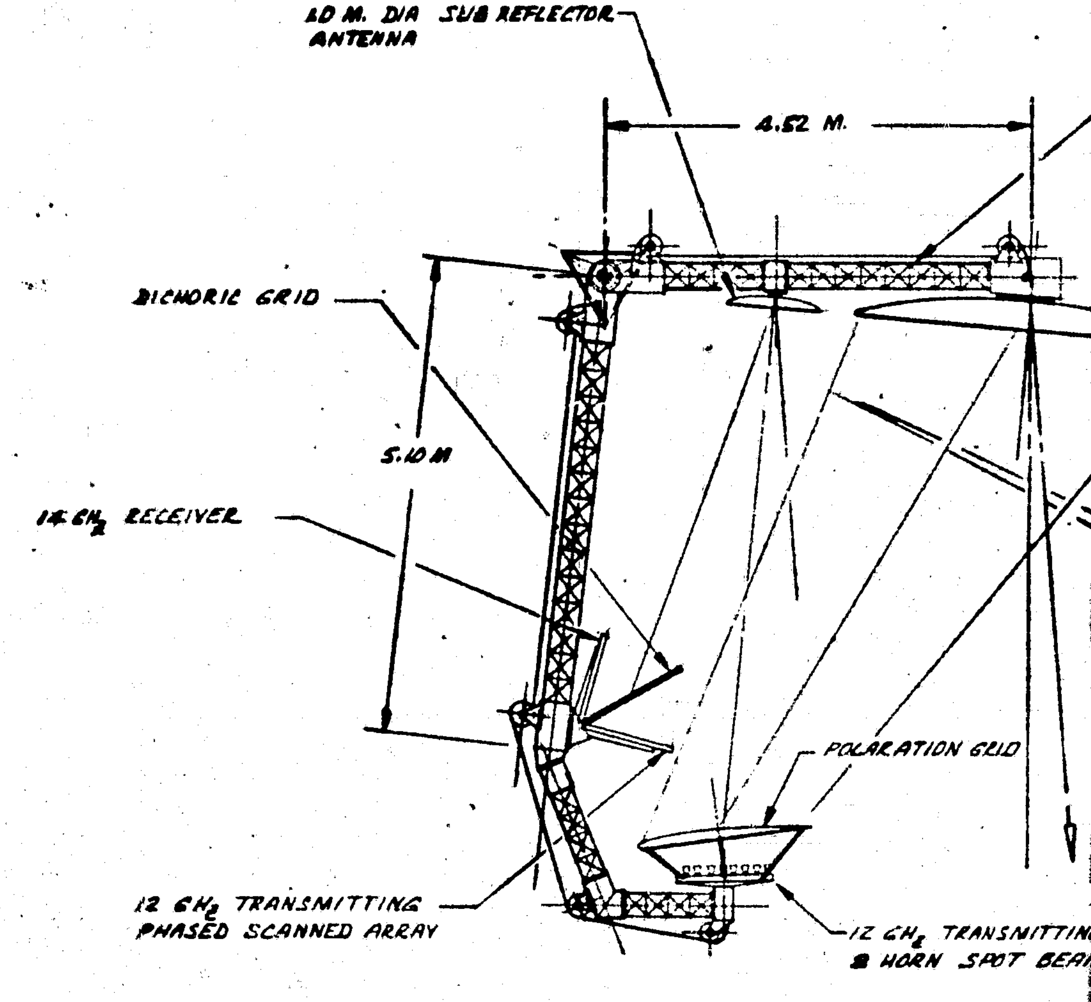
A-3,
A-4

A

SIZE	CODE IDENT NO	DRAWING NO.
L	03953	42662-45A
SCALE		SHEET 2 OF 3

26 | 25

C-4



SCAN PHASED AR

SCALE

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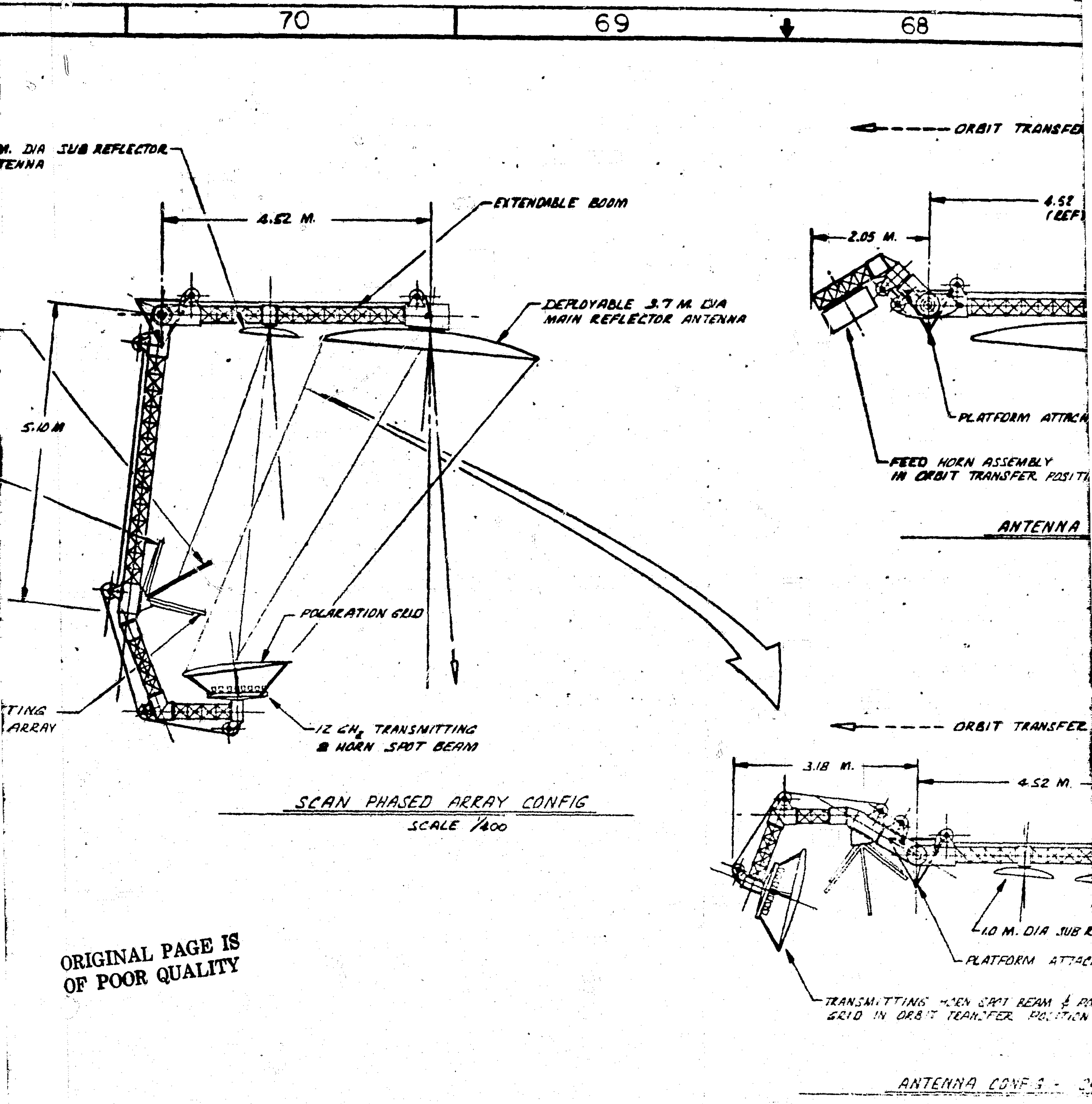
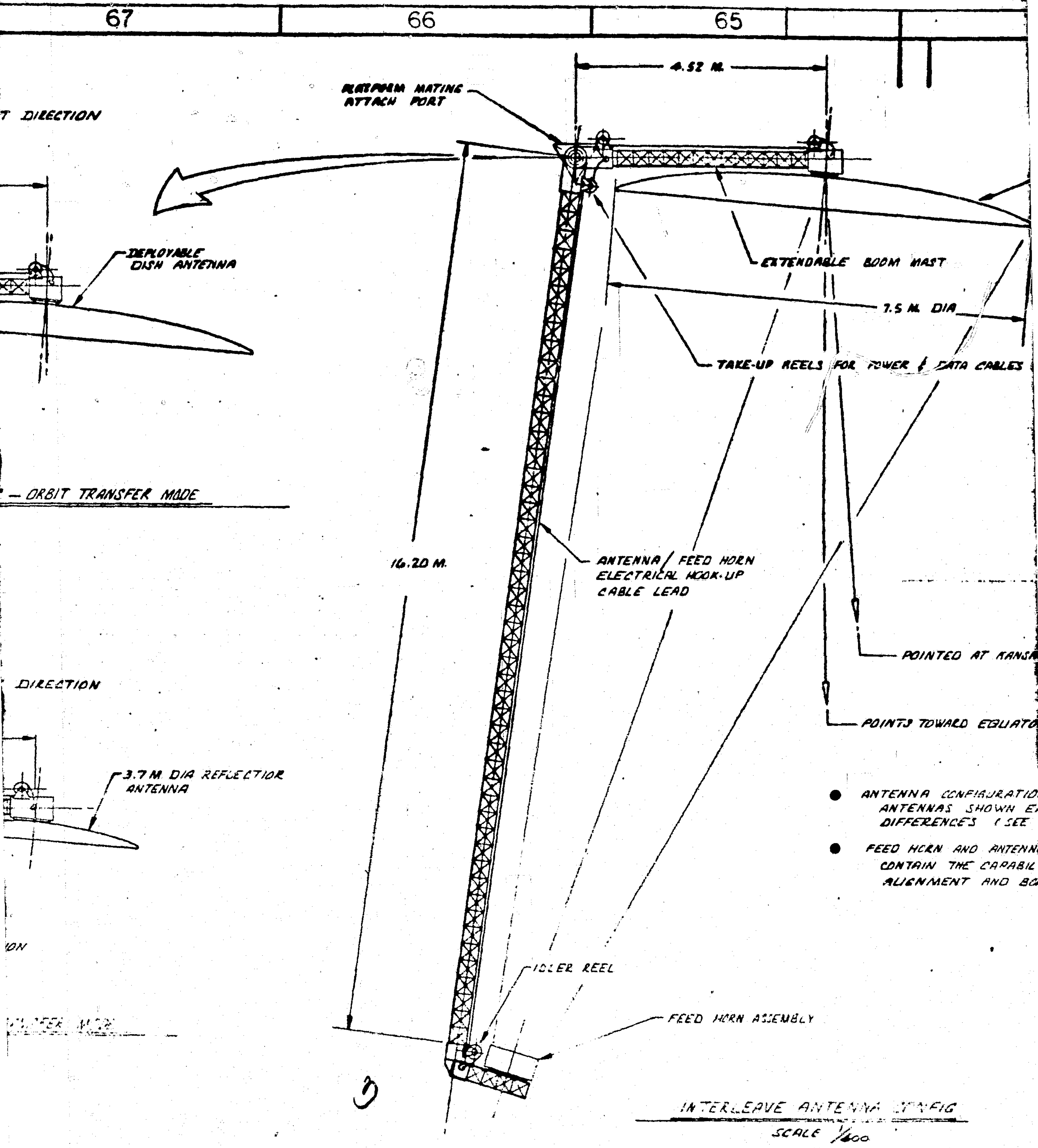
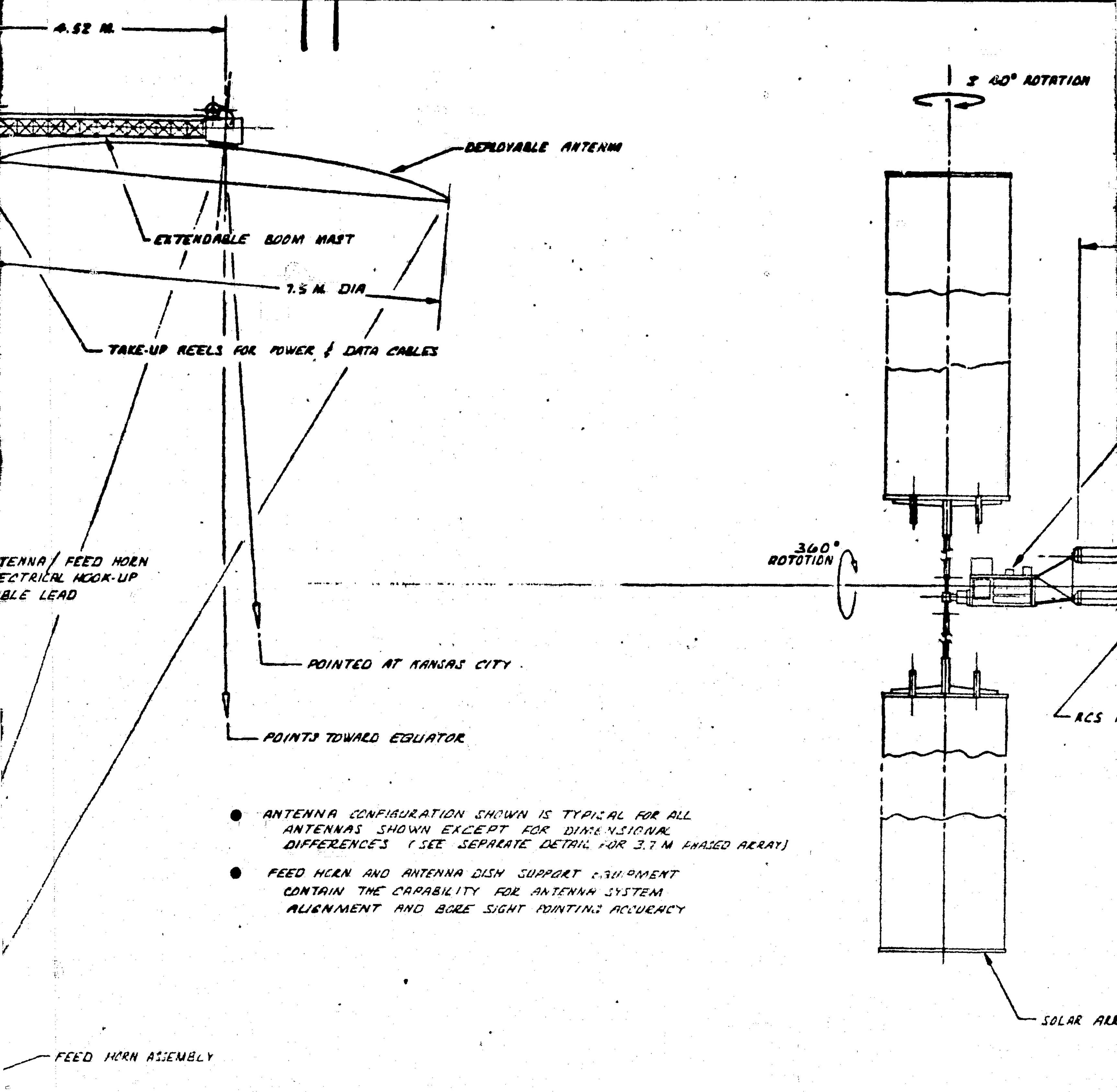
FOLDOUT FRAME


70
69
68
M. DIA SUB REFLECTOR
TENNA
4.52 M.
EXTENDABLE BOOM
DEPLOYABLE 3.7 M. DIA
MAIN REFLECTOR ANTENNA
5.10 M
POLARATION GRID
TING
ARRAY
12 GHz TRANSMITTING
8 HORN SPOT BEAM
SCAN PHASED ARRAY CONFIG
SCALE 1/400
ORBIT TRANSFER
4.52
(REF)
2.05 M.
PLATFORM ATTACH
FEED HORN ASSEMBLY
IN ORBIT TRANSFER POSITI
ANTENNA
ORBIT TRANSFER
3.18 M.
4.52 M.
1.0 M. DIA SUB R
PLATFORM ATTAC
TRANSMITTING HORN SPOT BEAM & PO
GRID IN ORBIT TRANSFER POSITION
ANTENNA CONF 3



FOLDOUT FRAME

42662-45A 3

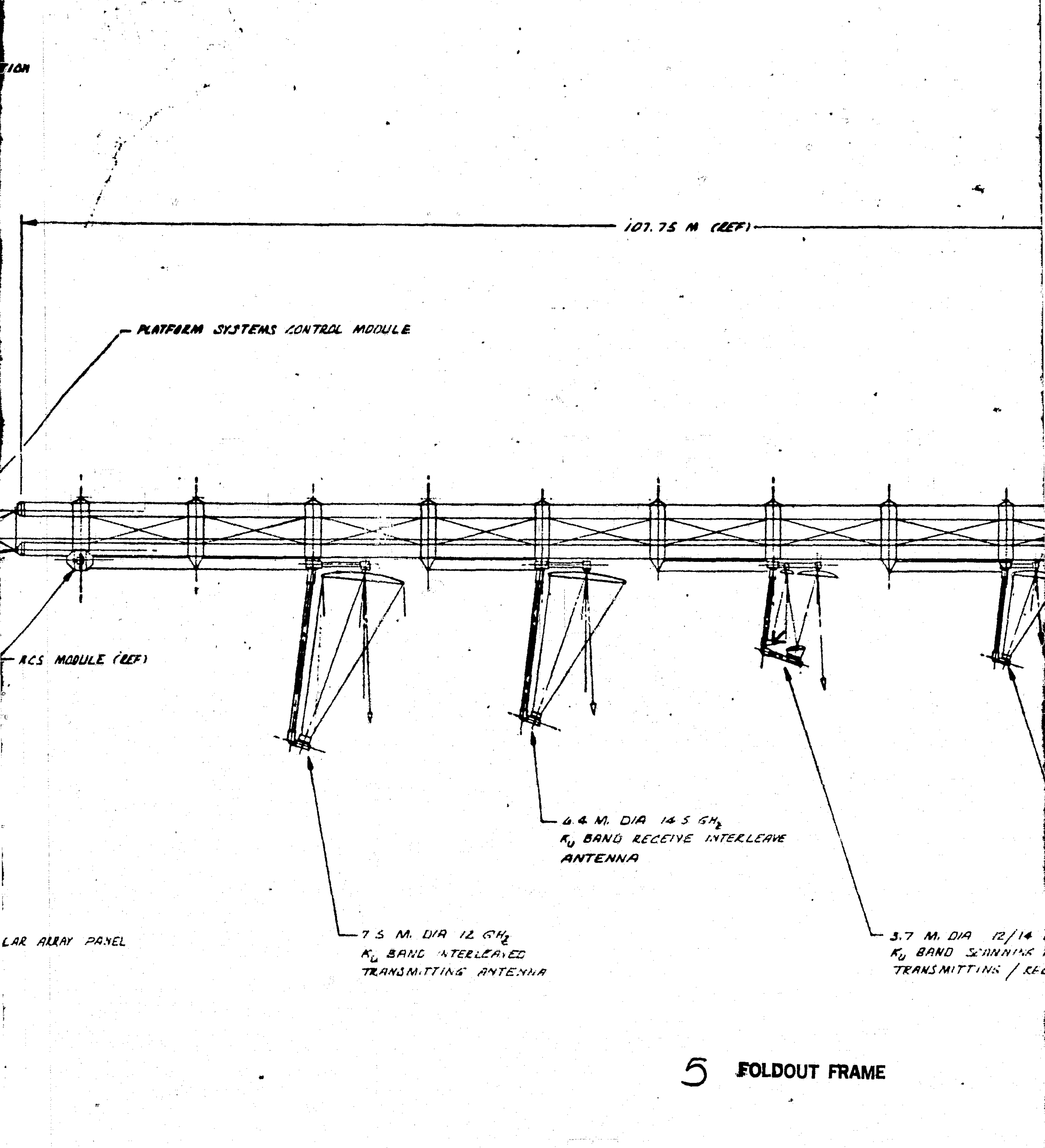


- ANTENNA CONFIGURATION SHOWN IS TYPICAL FOR ALL ANTENNAS SHOWN EXCEPT FOR DIMENSIONAL DIFFERENCES (SEE SEPARATE DETAIL FOR 3.7 M PHASED ARRAY)
- FEED HORN AND ANTENNA DISH SUPPORT EQUIPMENT CONTAIN THE CAPABILITY FOR ANTENNA SYSTEM ALIGNMENT AND BORE SIGHT POINTING ACCURACY

INTERLEAVE ANTENNA CONFIG
SCALE 1/400

4 FOLDOUT FRAME

42662-45A | 3



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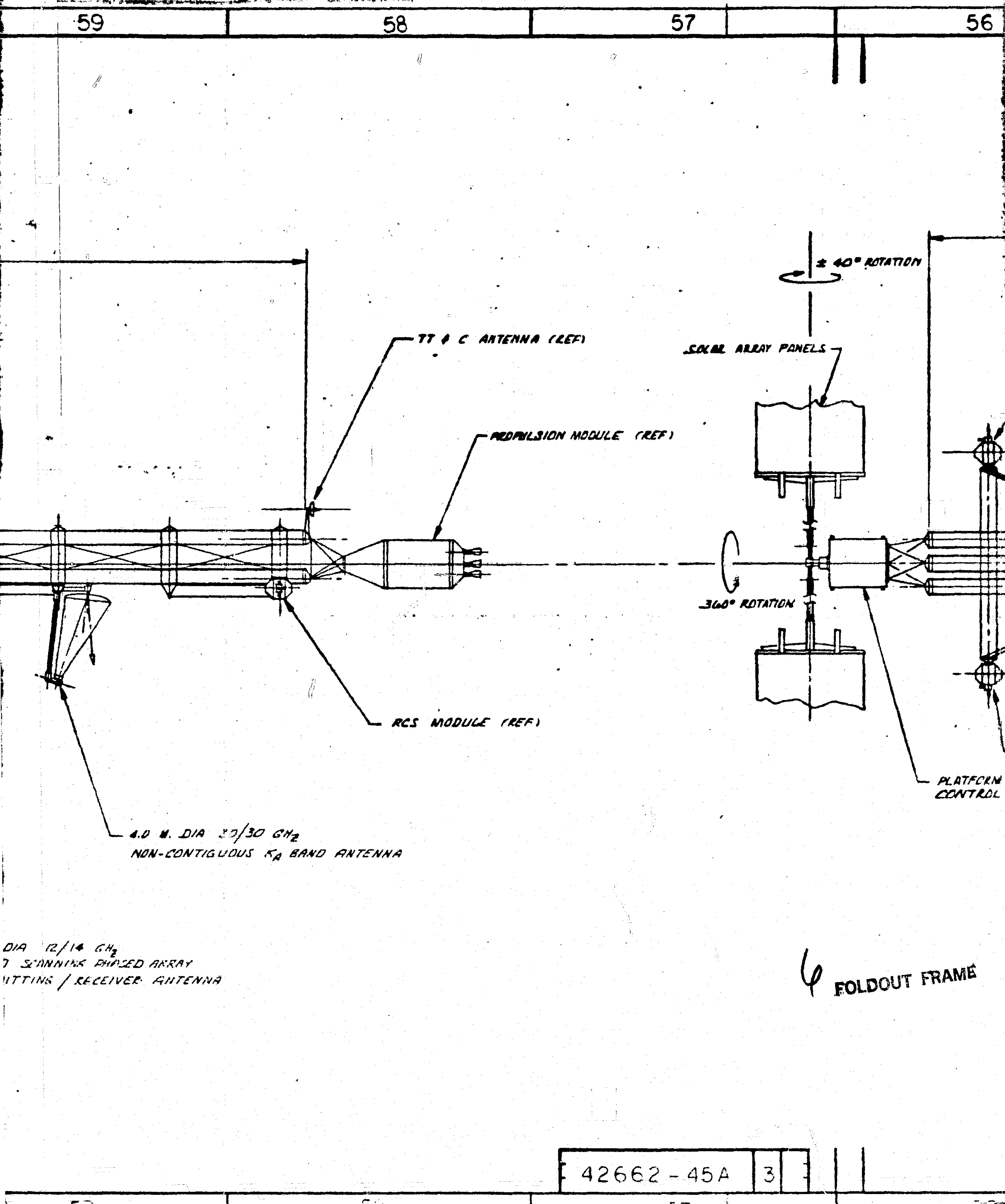

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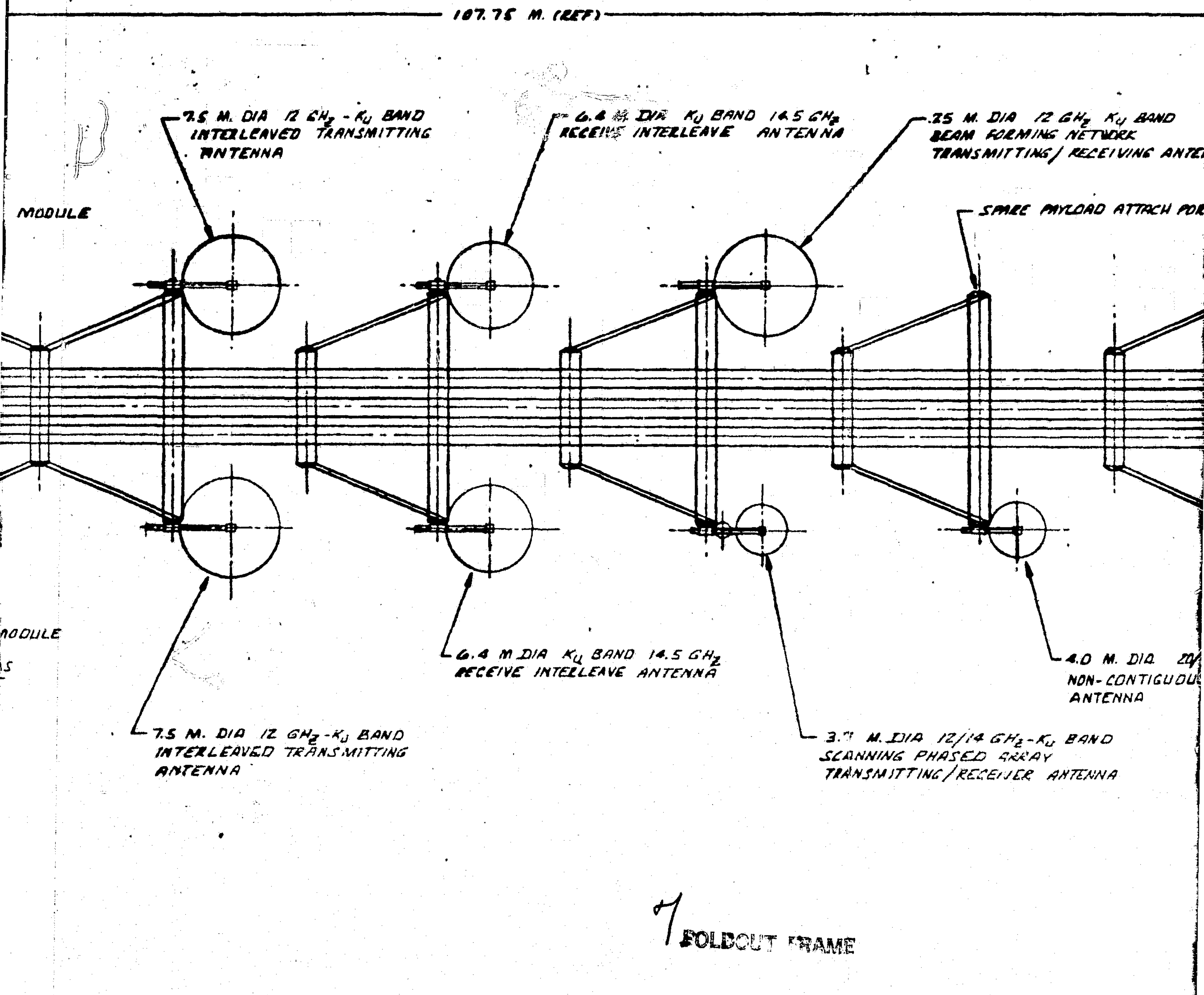

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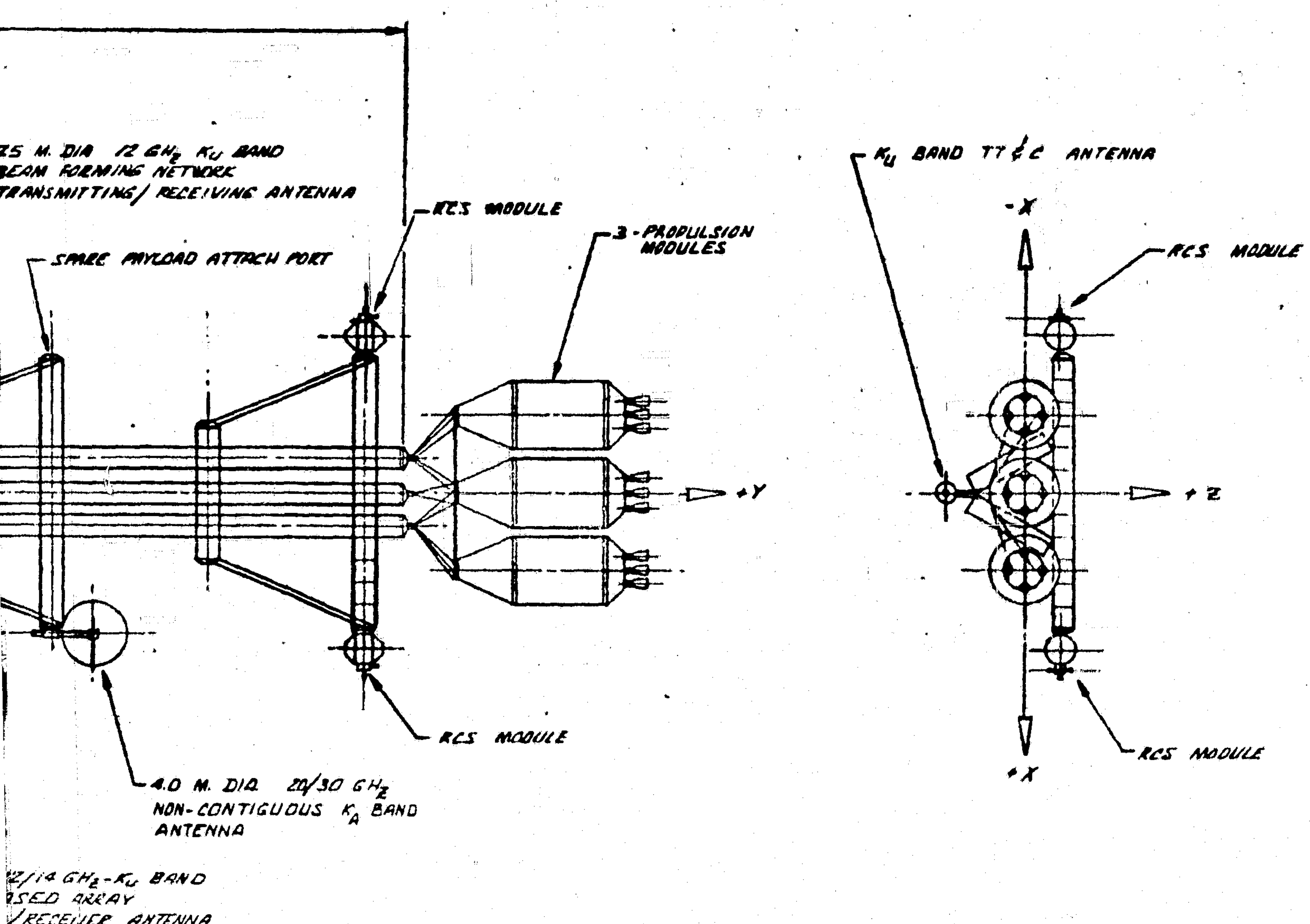
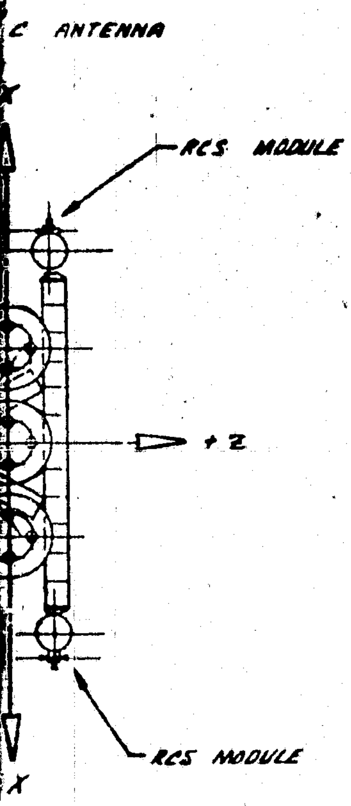


.75 M. DIA 12 GHz KU BAND
BEAM FORMING NETWORK
TRANSMITTING/ RECEIVING ANTENNA
SPARE PAYLOAD ATTACH PORT
RCS MODULE
3 - PROPULSION MODULES
+Y
KU BAND TT & C ANTENNA
-X
RCS MODULE
+Z
RCS MODULE
+X
RCS MODULE
4.0 M. DIA 20/30 GHz
NON-CONTIGUOUS KA BAND
ANTENNA
12/14 GHz - KU BAND
PHASED ARRAY
/RECEIVER ANTENNA

50 49

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

D



C

B

42662-45A 3

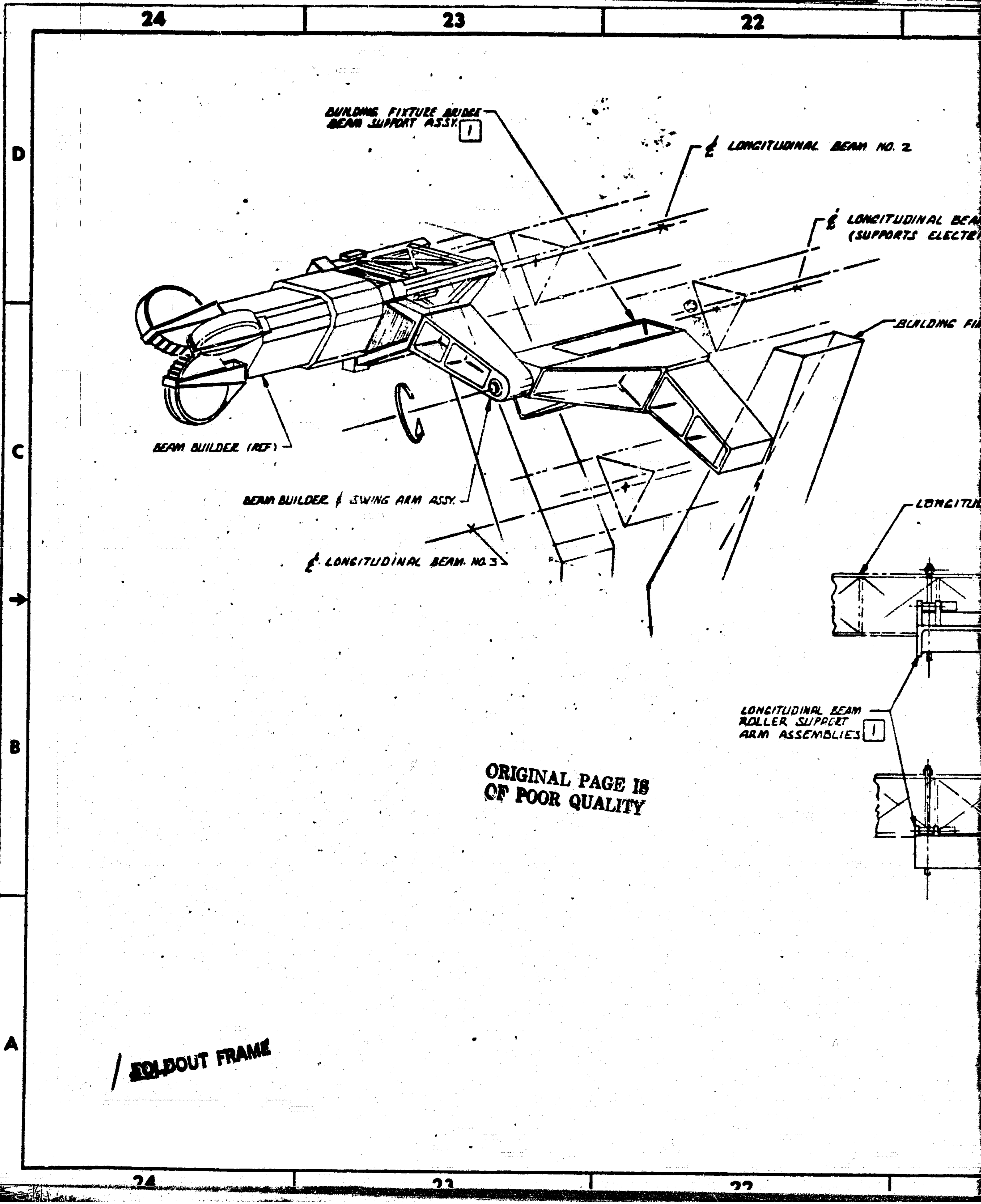
9 FOLDOUT FRAME

A-5,
A-6

A

SIZE	CODE IDENT NO	DRAWING NO
L	03953	42662-45A
SCALE		SHEET

50 49



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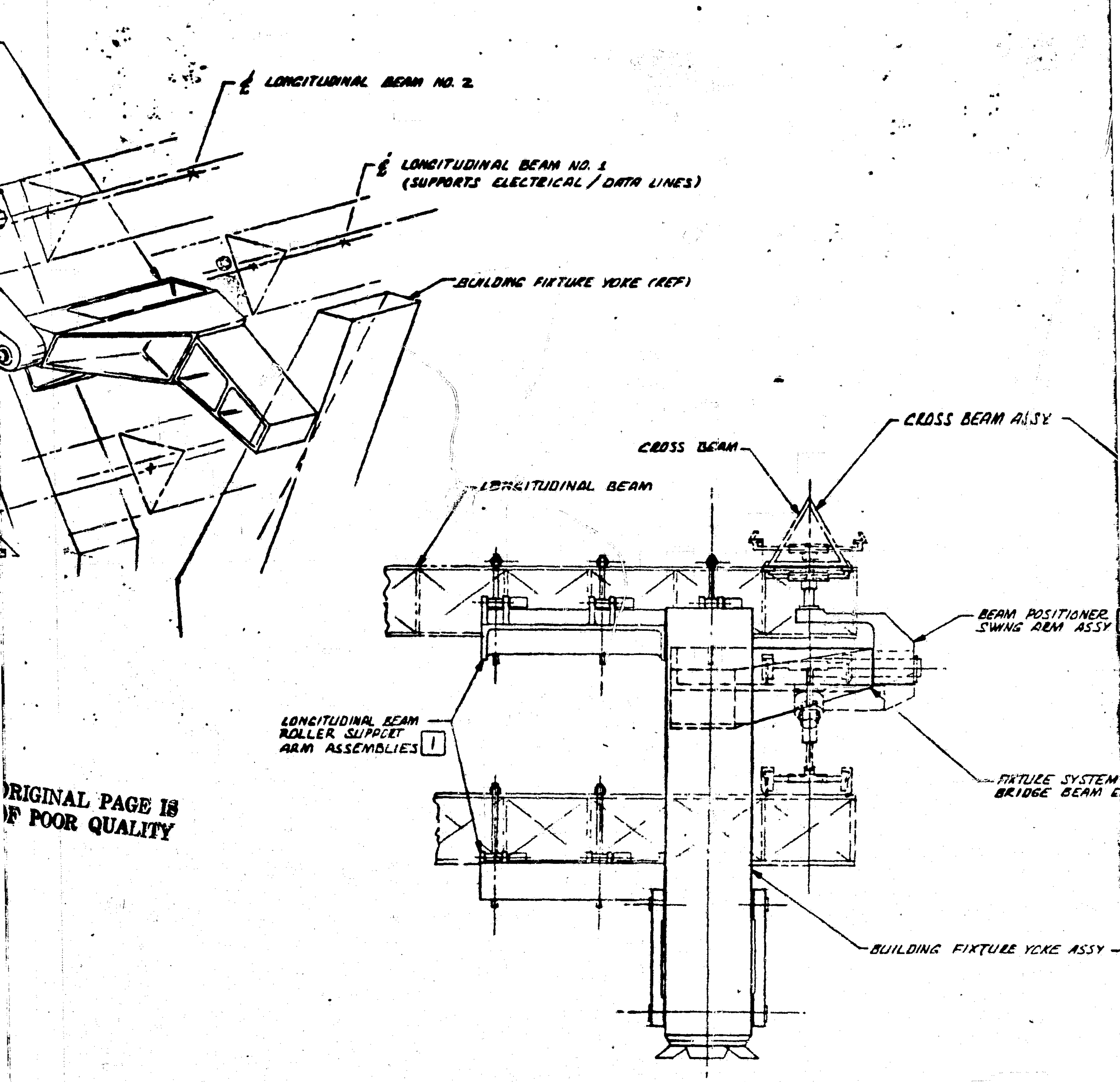
FOLDOUT FRAME



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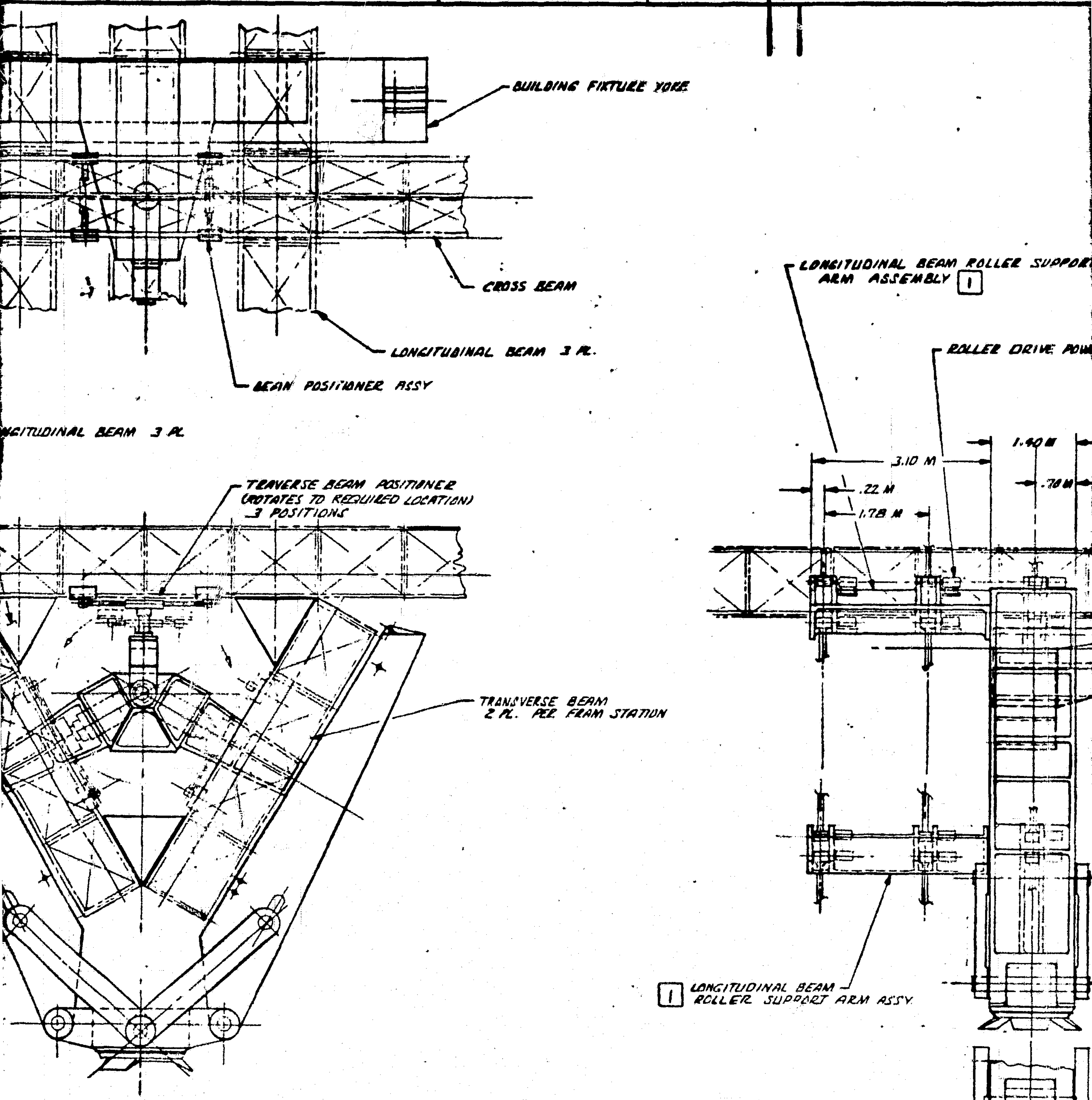
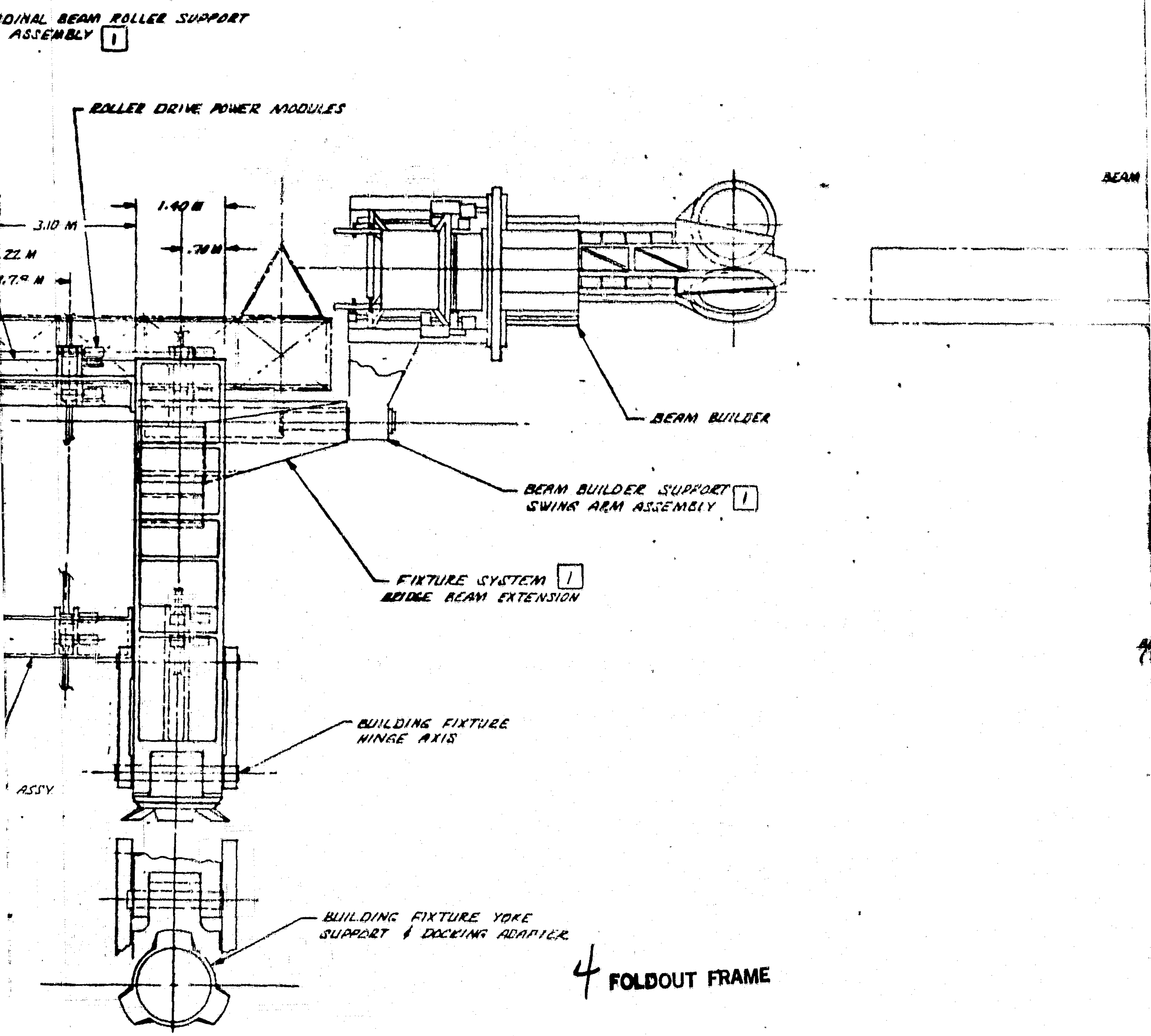
FOLDOUT FRAME 2



3 FOLDOUT FRAME

42662-50 1



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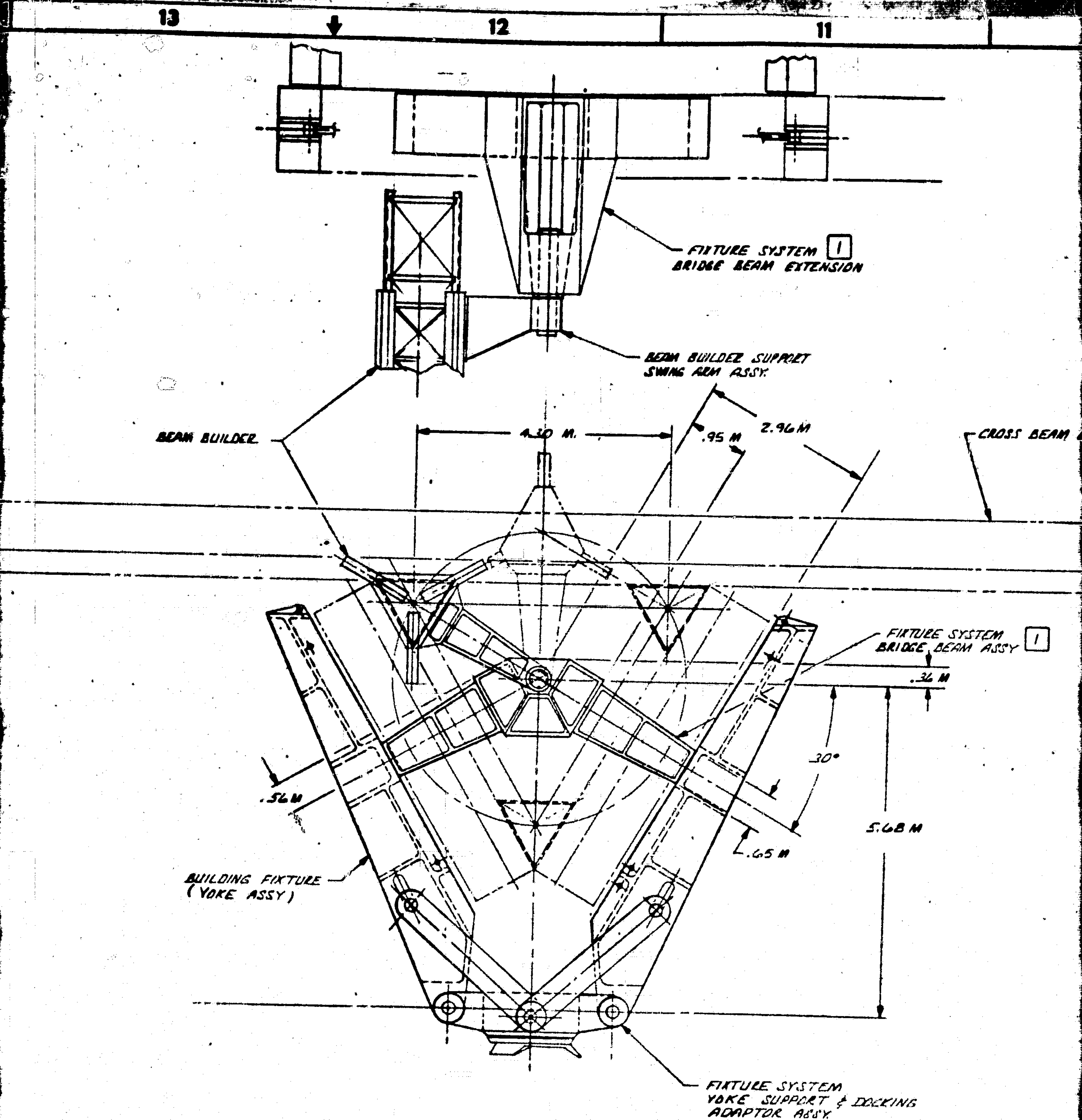

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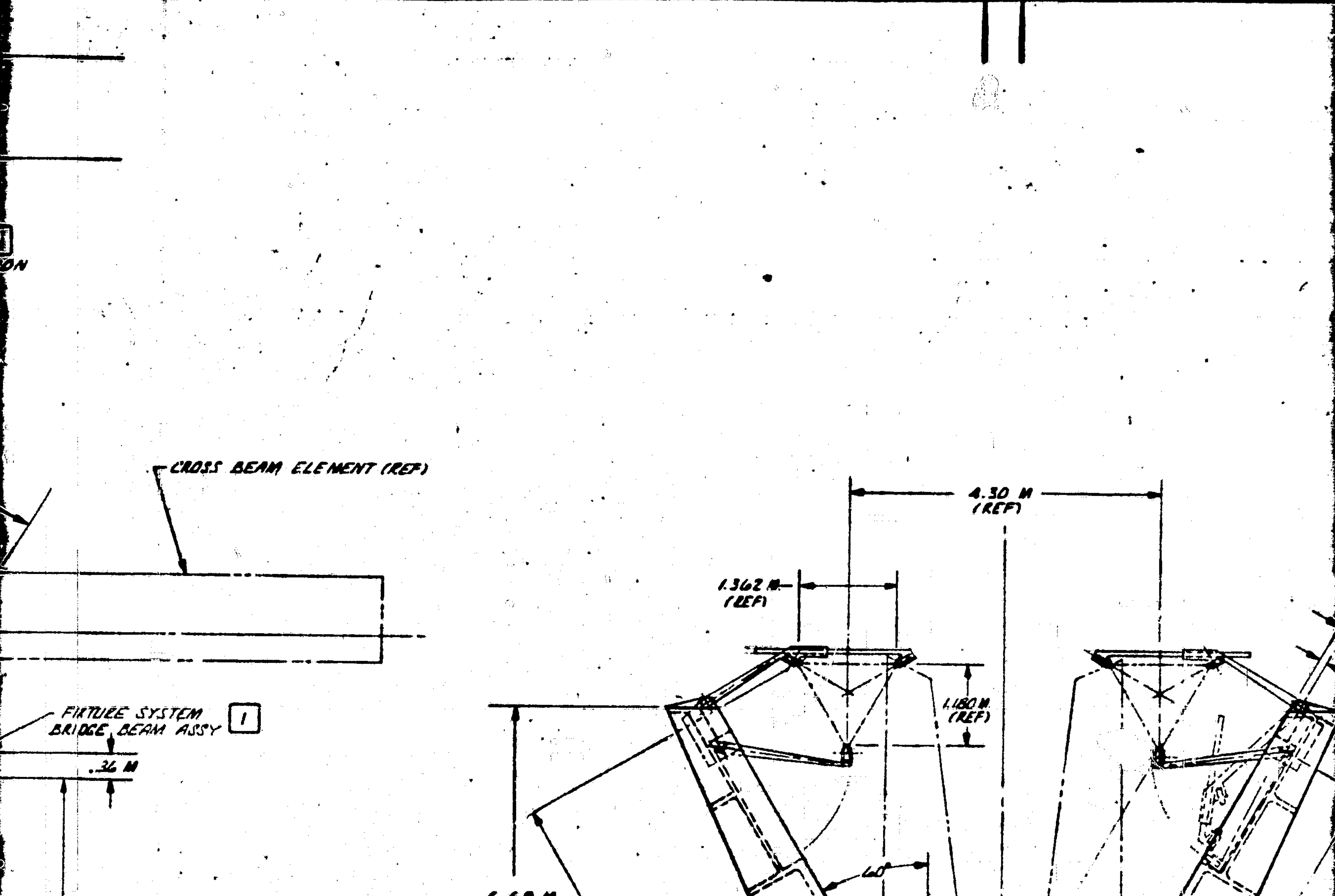
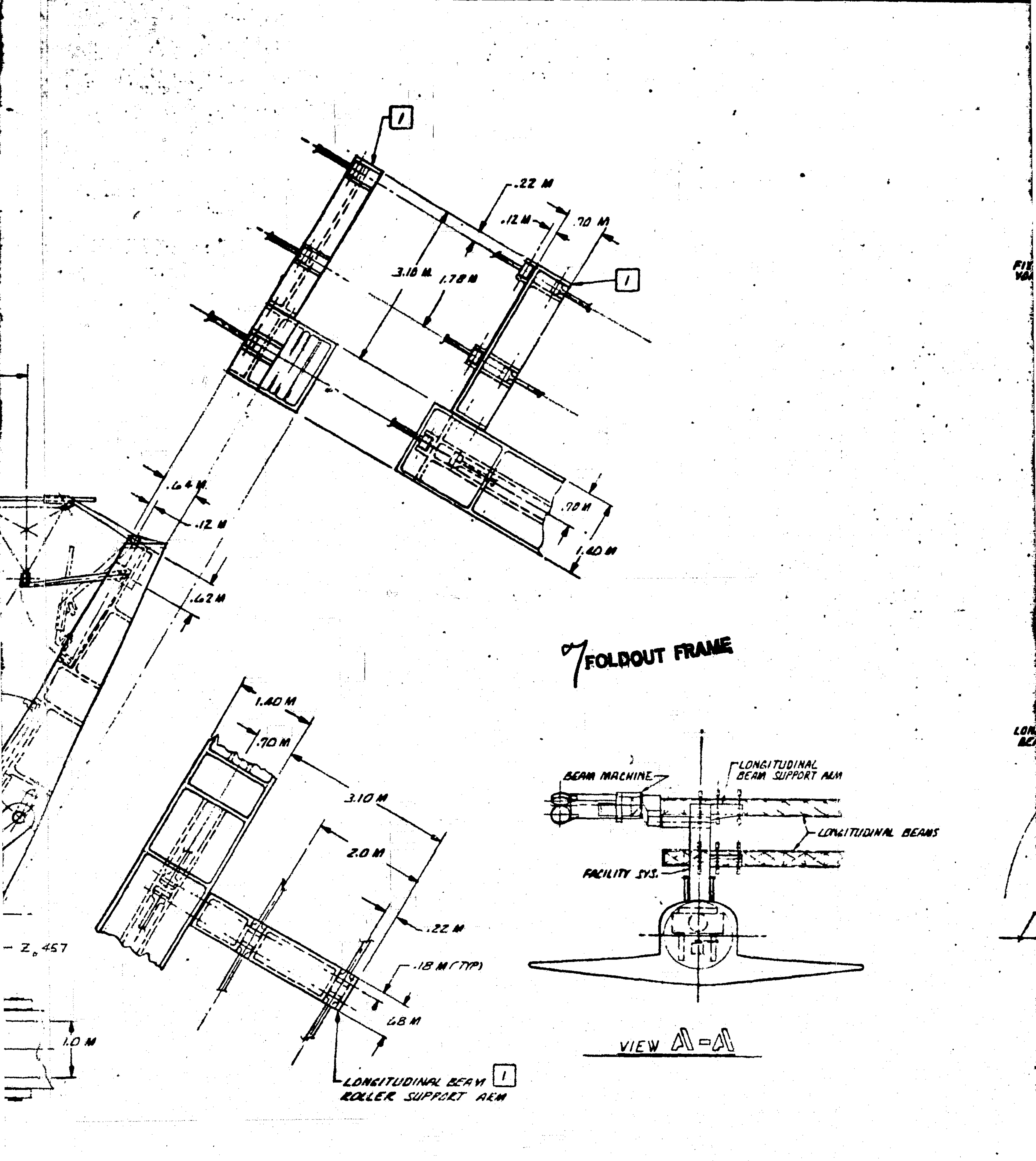
FOLDOUT FRAME



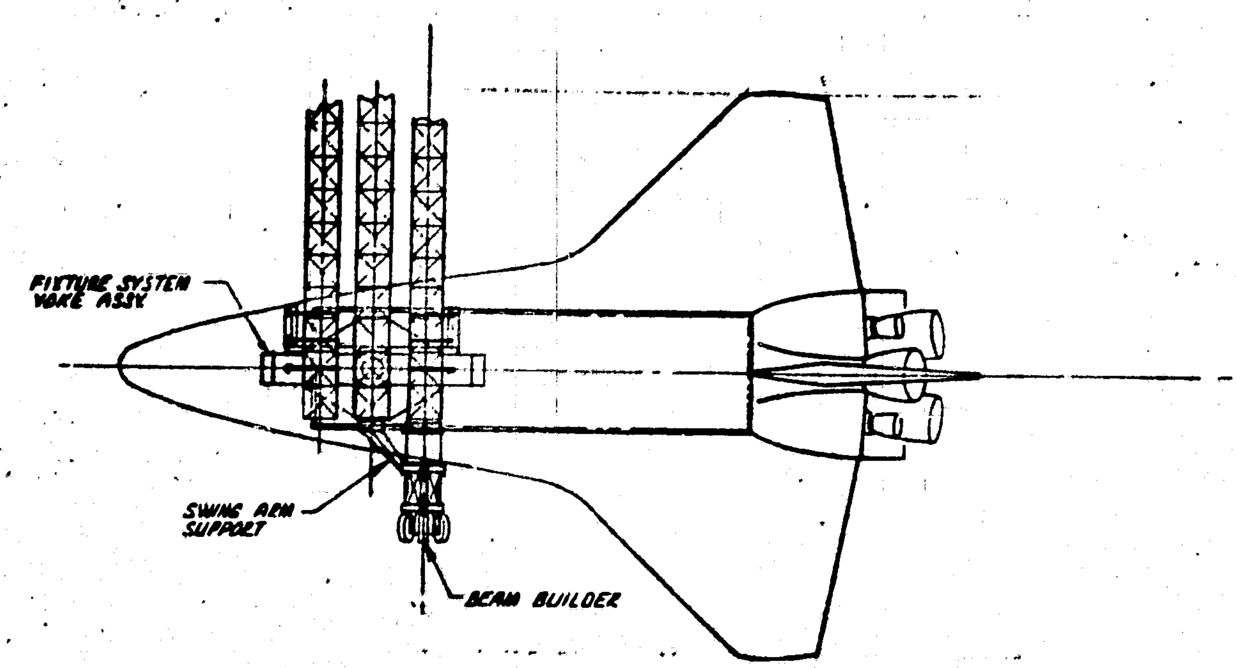
6 FOLDOUT FRAME

UT FRAME

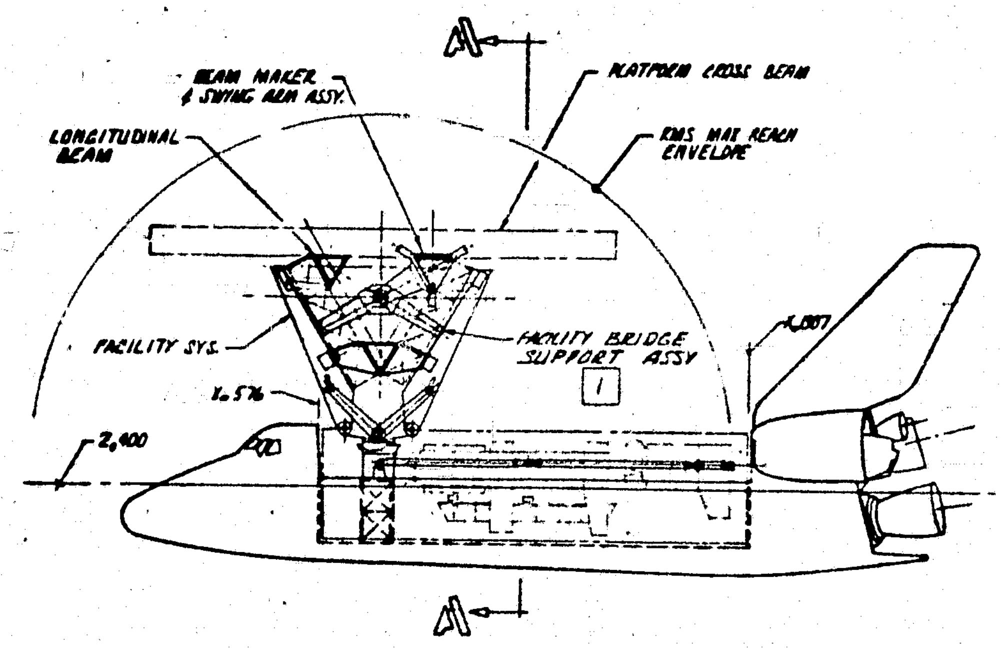
42662-50 | 1



1
.22 M
.12 M
.70 M
3.10 M
1.78 M
1
.64 M
.12 M
.62 M
.70 M
1.40 M
FOLDOUT FRAME
1.40 M
.70 M
3.10 M
2.0 M
.22 M
.18 M (TYP)
.68 M
Z₀ 457
1.0 M
LONGITUDINAL BEAM
ROLLER SUPPORT ARM
1
BEAM MACHINE
LONGITUDINAL
BEAM SUPPORT ARM
LONGITUDINAL BEAMS
FACILITY SYS.
VIEW A-A



8 FOLDOUT FRAME



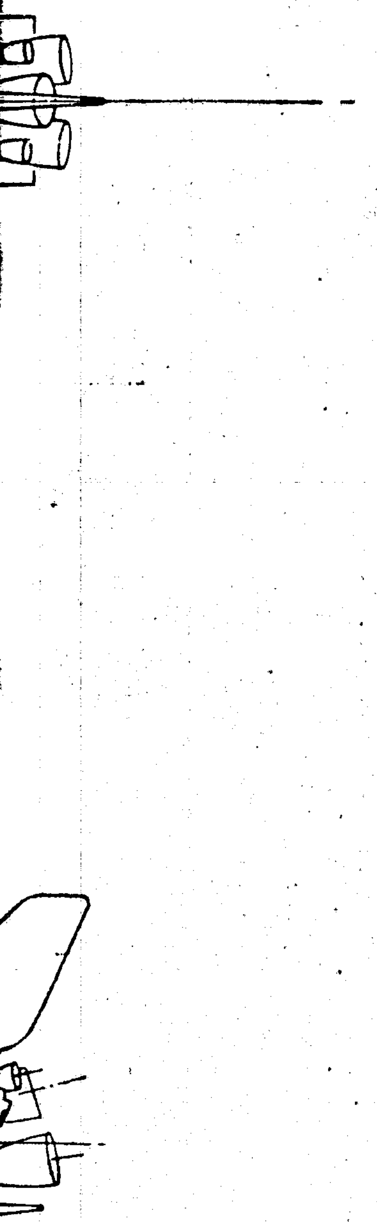
ITUDINAL BEAMS

3	2	1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	SEE SHEET NO. 4 FOR DESIGN CHANGES MADE AS A RESULT OF AUTOMATED ASSEMBLY REQUIREMENTS	11-19-79	[signature]
	2	SEE SHEET NO. 3 FOR ADDITION OF LIBRATION DAMPER SYSTEM	11-21-79	[signature]

D



FOLDOUT FRAME

C

B

A-7,
A-8

A

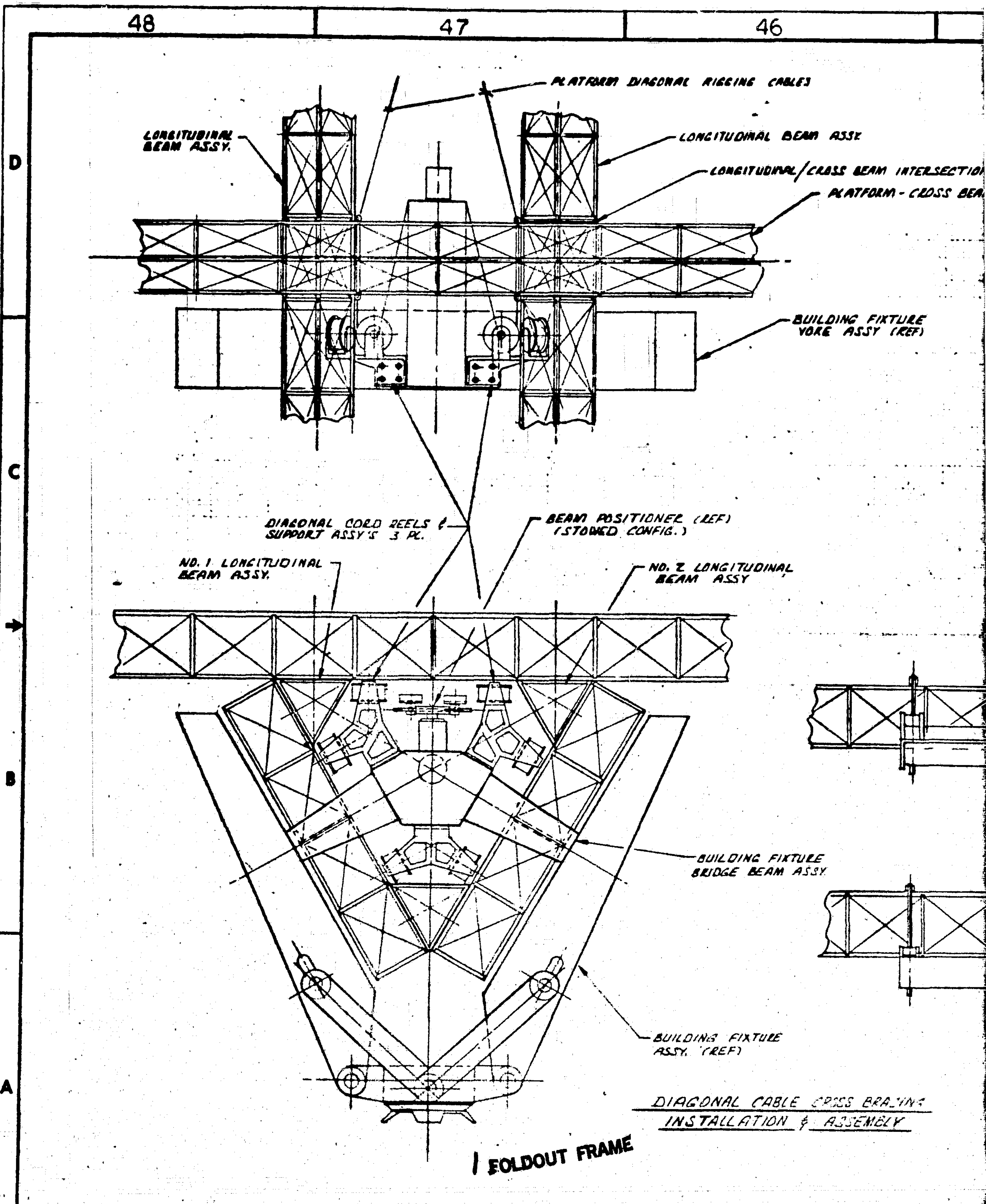
DR BY	Thompson 9-28-79
CHK BY	
APPROVED BY	

Rockwell International Corporation
Space Division
12214 Lakewood Boulevard • Downey, California 90241

TRI-BEAM CONSTRUCTION FACILITY SYSTEM & OPERATIONS, CONFIGURATION OF

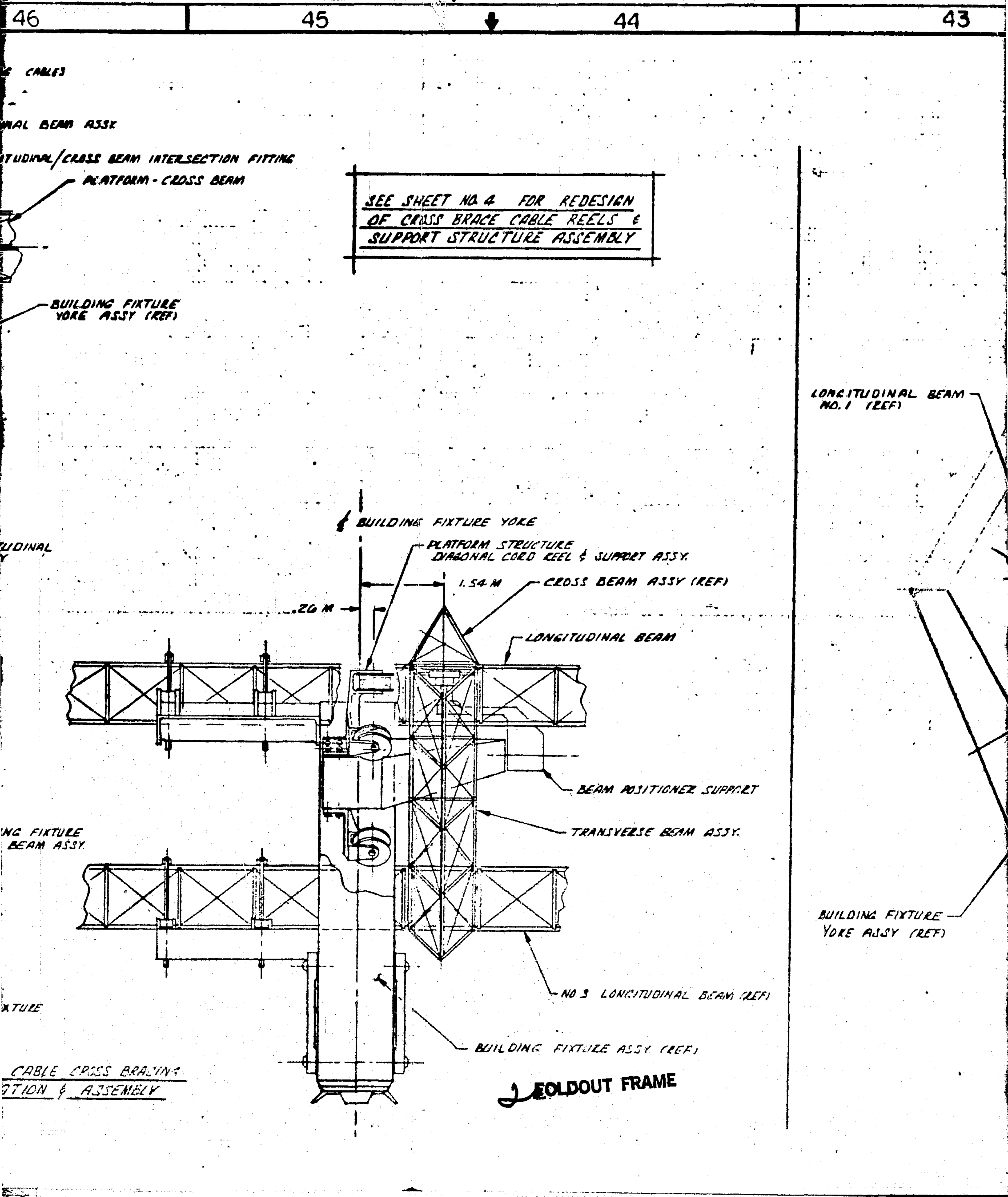
SIZE	CODE IDENT NO	DRAWING NO.
L	03953	42662-50

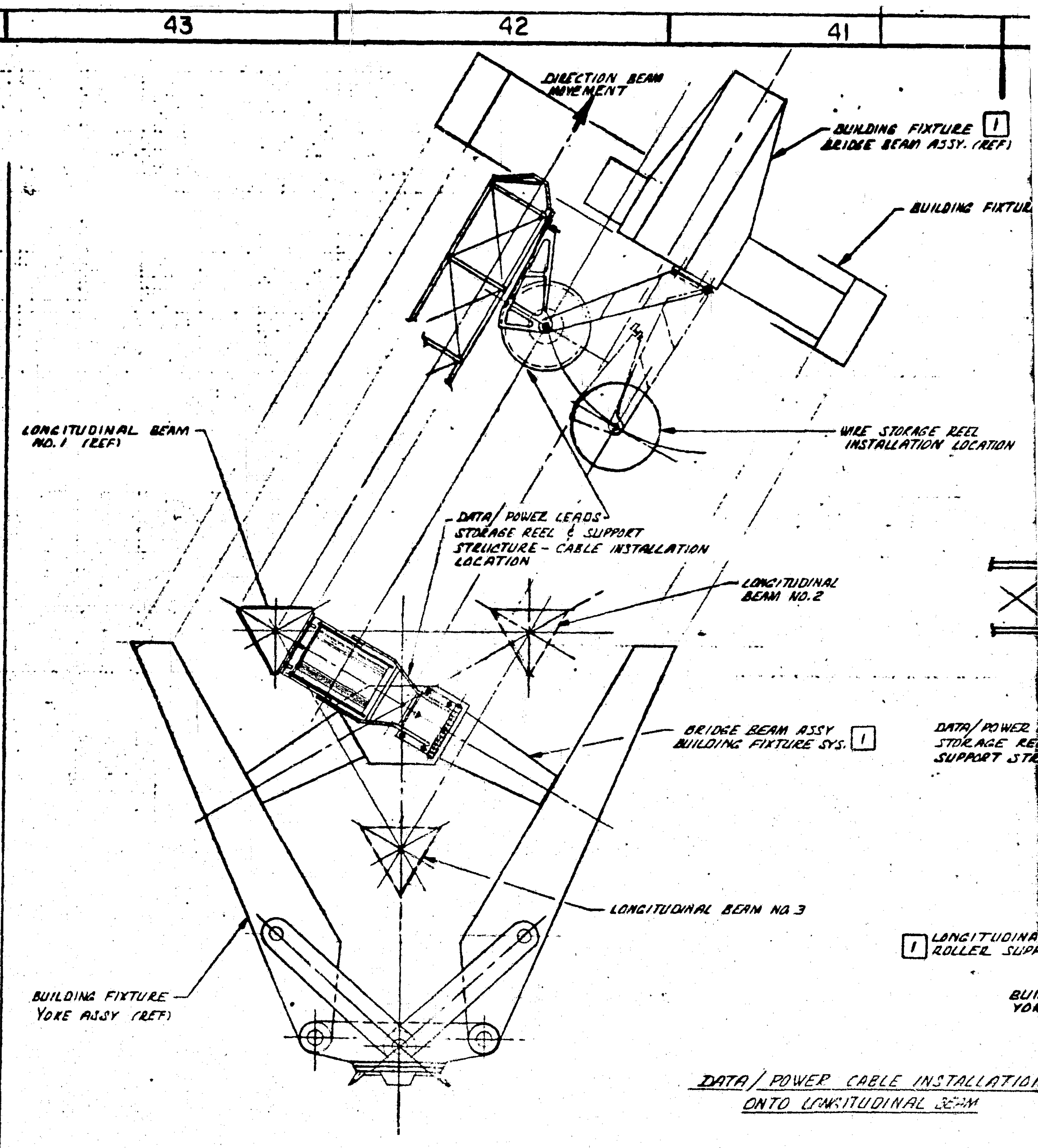
SCALE | SHEET 1 OF 2



DIAGONAL CABLE CROSS BRACING
INSTALLATION & ASSEMBLY

FOLDOUT FRAME

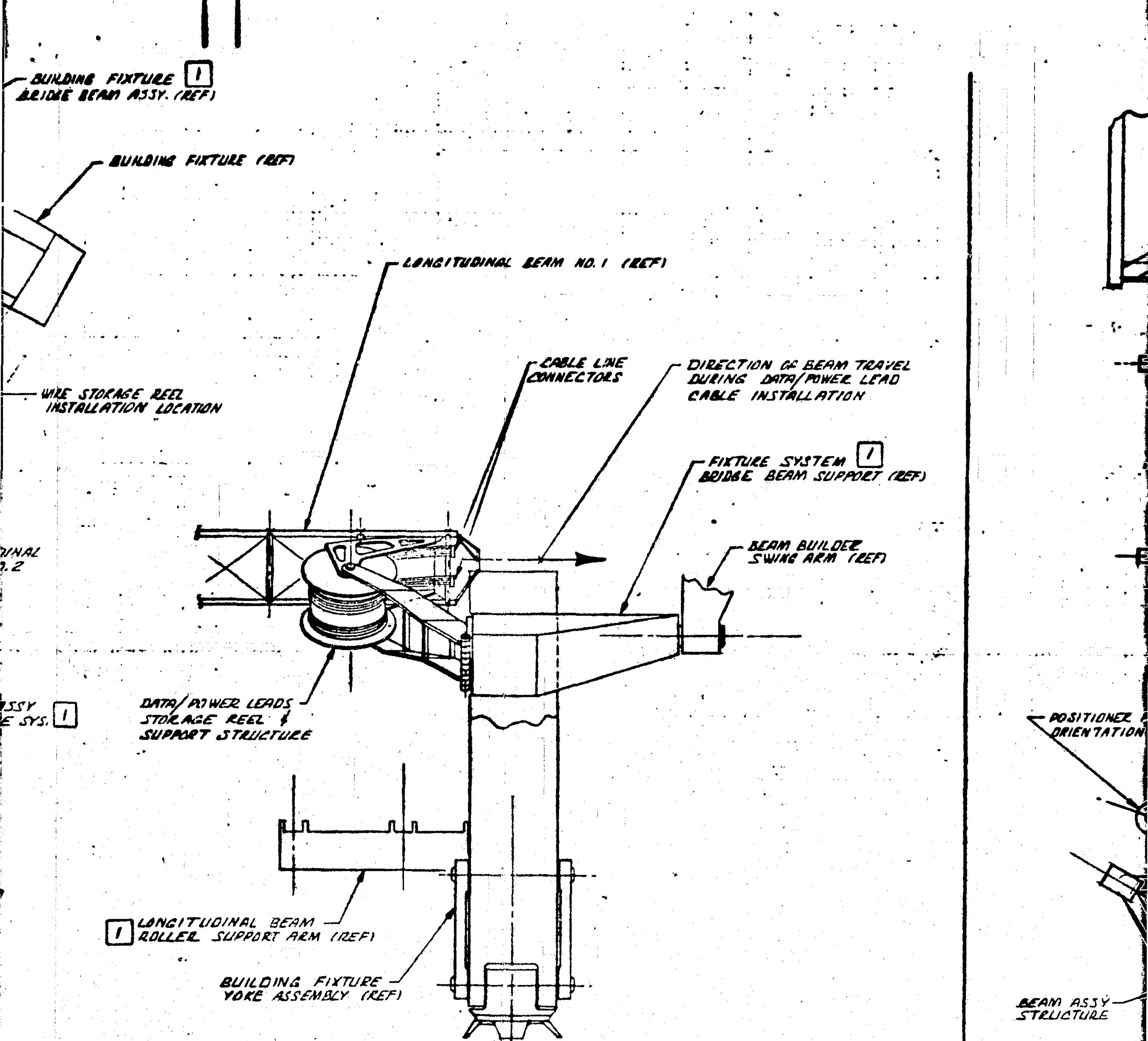

46
45
44
43
CABLES
NAL BEAM ASSY
TUDINAL/CROSS BEAM INTERSECTION FITTING
PLATFORM - CROSS BEAM
SEE SHEET NO. 4 FOR REDESIGN OF CROSS BRACE CABLE REELS & SUPPORT STRUCTURE ASSEMBLY
BUILDING FIXTURE YOKE ASSY (REF)
BUILDING FIXTURE YOKE
PLATFORM STRUCTURE DIAGONAL CORD REEL & SUPPORT ASSY.
1.54 M
CROSS BEAM ASSY (REF)
.26 M
LONGITUDINAL BEAM
BEAM POSITIONER SUPPORT
TRANSVERSE BEAM ASSY.
NO. 3 LONGITUDINAL BEAM (REF)
BUILDING FIXTURE ASSY (REF)
LONGITUDINAL BEAM NO. 1 (REF)
BUILDING FIXTURE YOKE ASSY (REF)
CABLE CROSS BRACING
TION & ASSEMBLY
FOLDOUT FRAME



DATA/POWER CABLE INSTALLATIO ONTO LONGITUDINAL BEAM

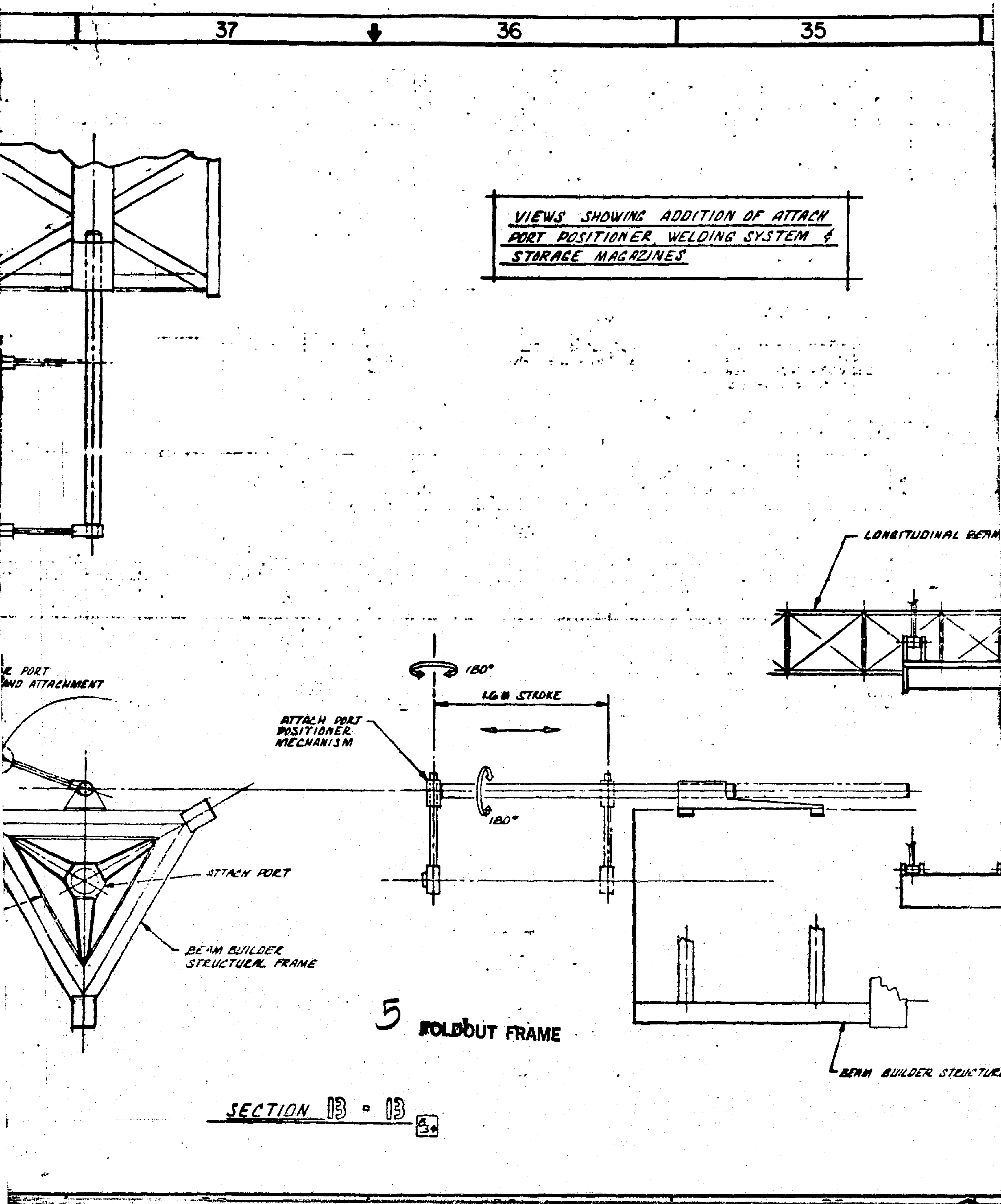
3 FOLDOUT FRAME

42662-50 | 2



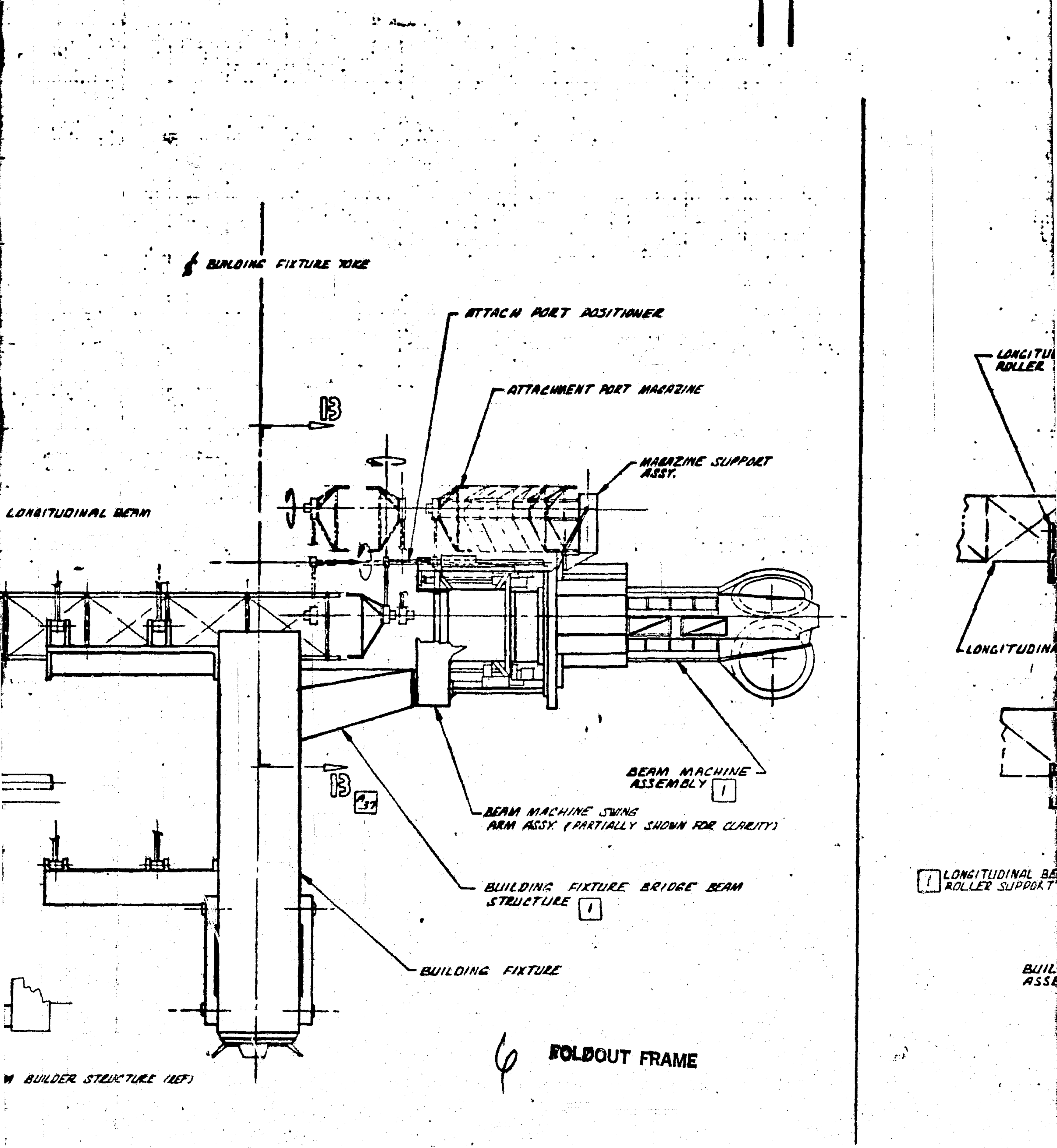
WER CABLE INSTALLATION
LONGITUDINAL BEAM

4 FOLDOUT FRAME



5 FOLDOUT FRAME

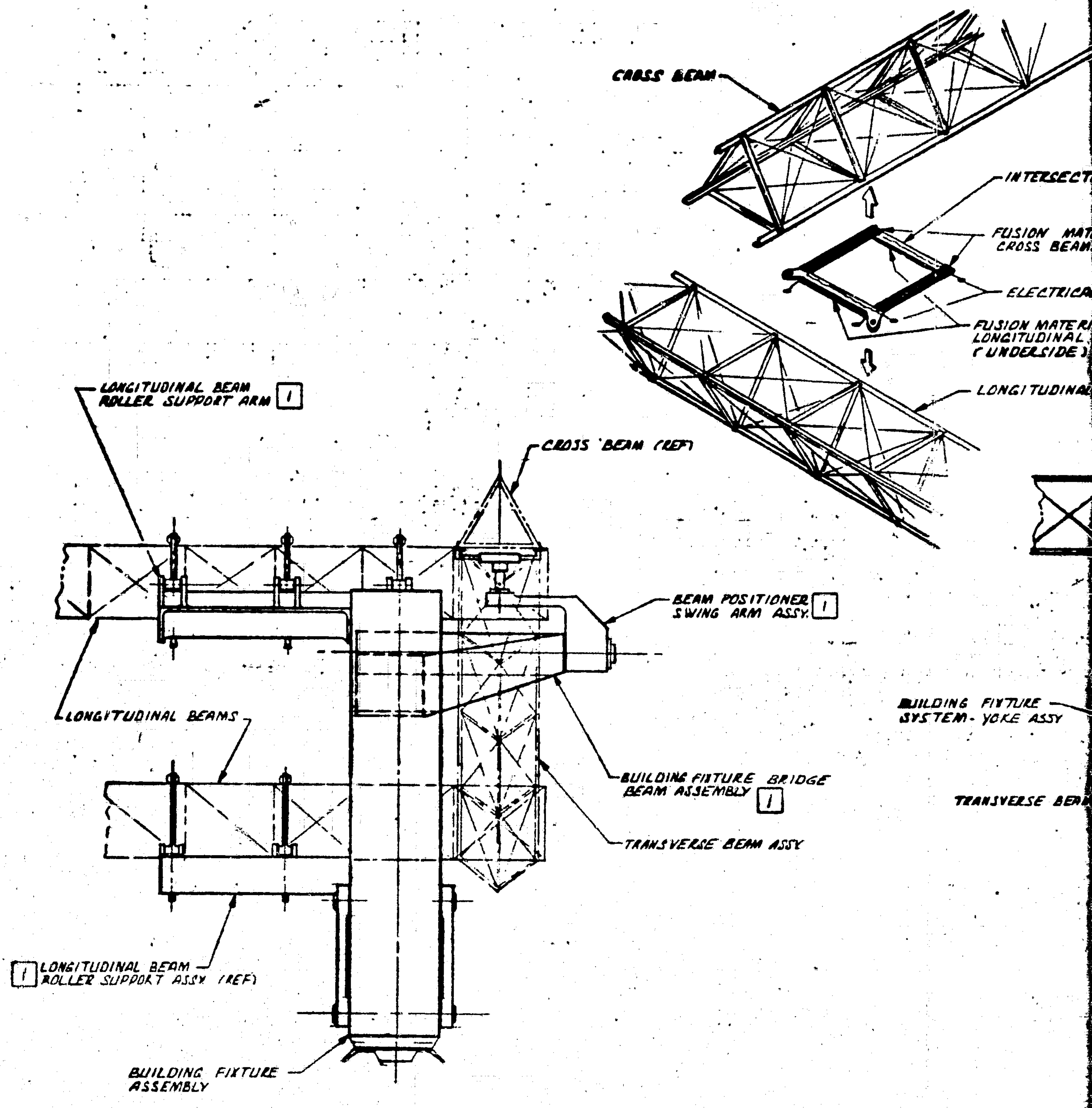
34	33	32



6 FOLDOUT FRAME

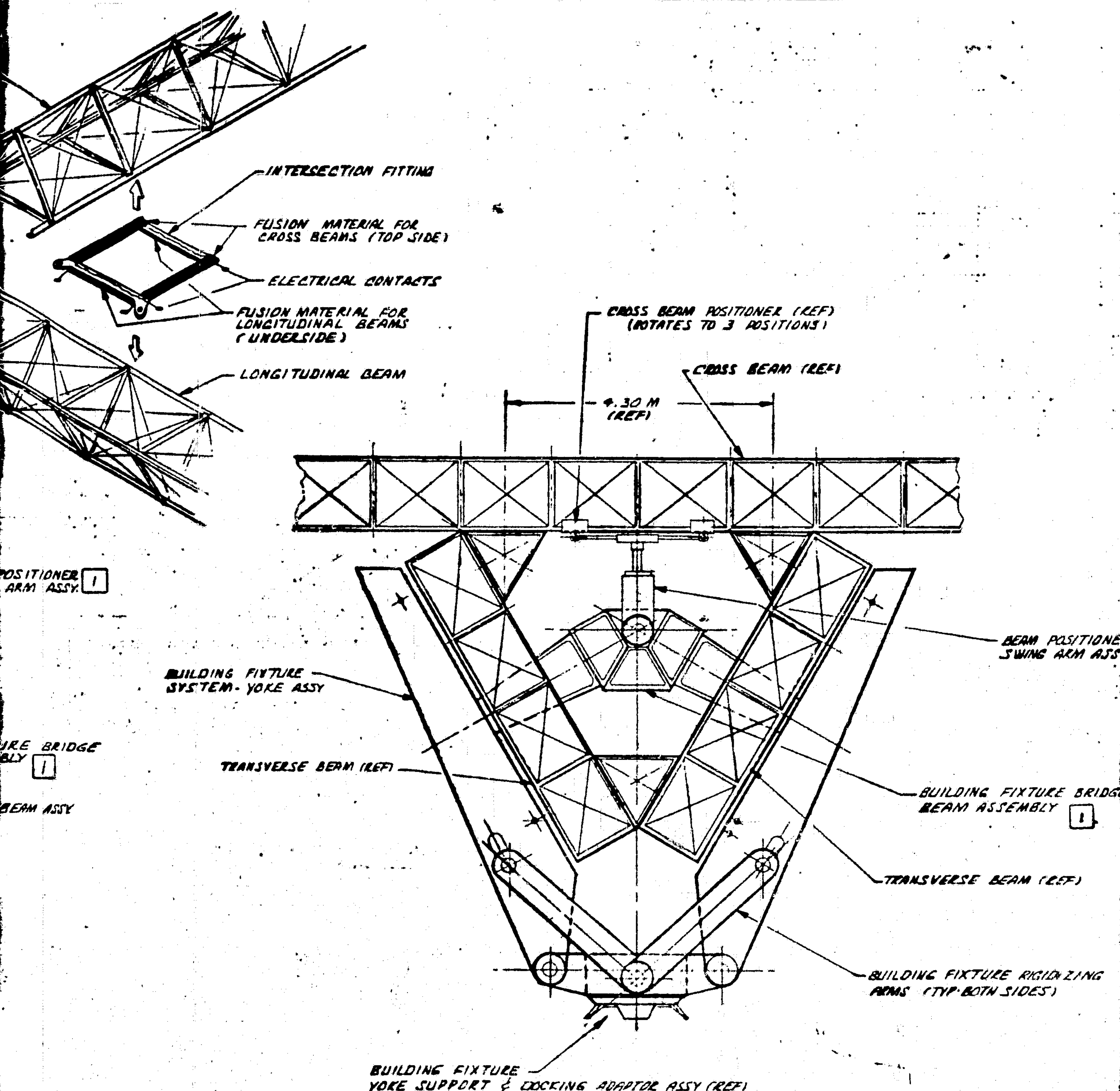
42662-50 | 2

32 31 30



FOLDOUT FRAME

DETAILS AND ASSEMBLY OF
PLATFORM BEAMS & INTERSECTION FITT



FOLDOUT FRAME

DETAILS AND ASSEMBLY OF
FORM BEAMS & INTERSECTION FITTINGS

26 25

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	SEE SHEET NO. 4 FOR DESIGN CHANGES MADE AS A RESULT OF AUTOMATED ASSEMBLY REQUIREMENTS	11-19-79	[signature]
	2	SEE SHEET NO. 3 FOR ADDITION OF LIBRATION DAMPER SYSTEM	11-21-79	

D

C

RM POSITIONER 1
WING ARM ASSY

XTURE BRIDGE
MBLY 1

B

2

42662-50

M (REF)

RIGIDIZING
DES)

9 FOLDOUT FRAME

A

A-9,
A-10

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662-50
SCALE		SHEET _ OF 4

26 25

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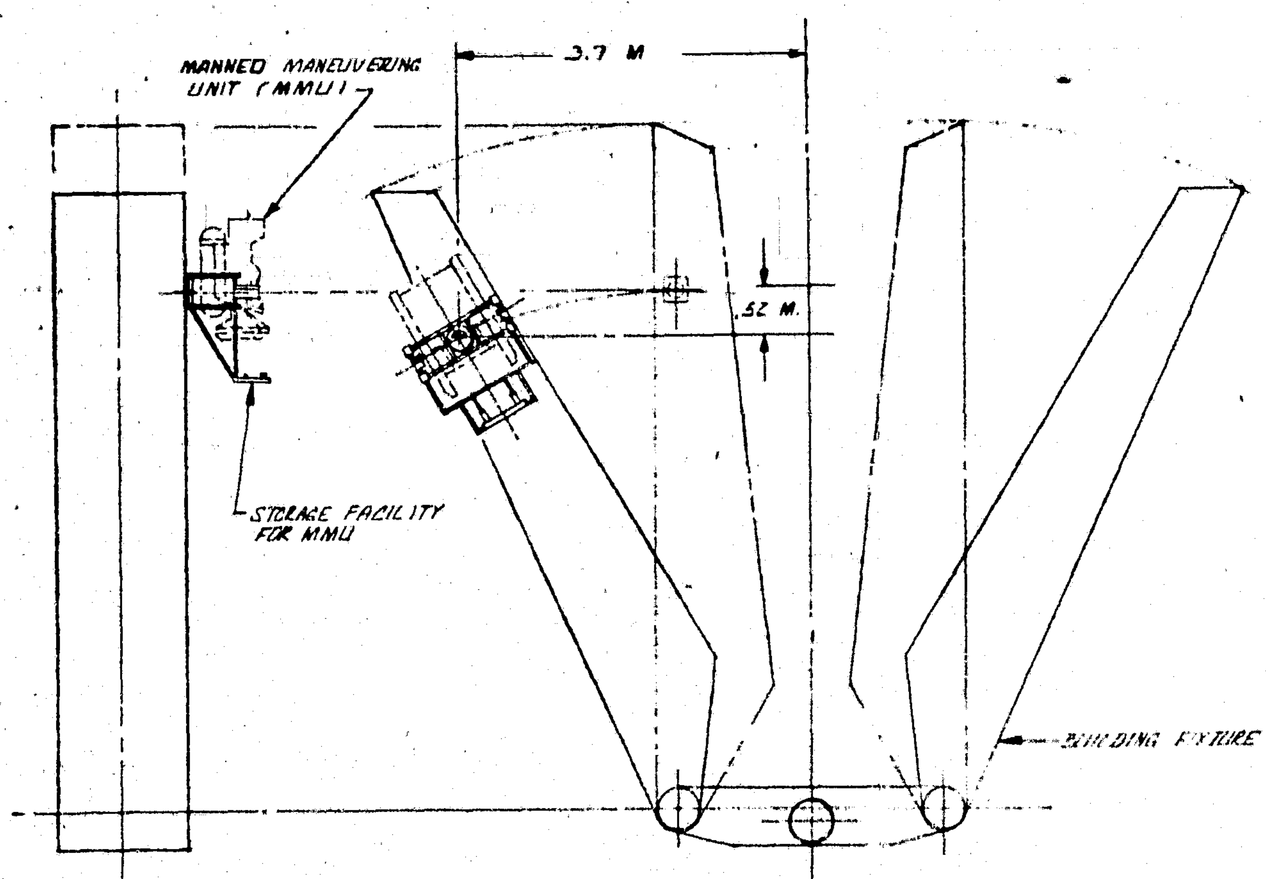
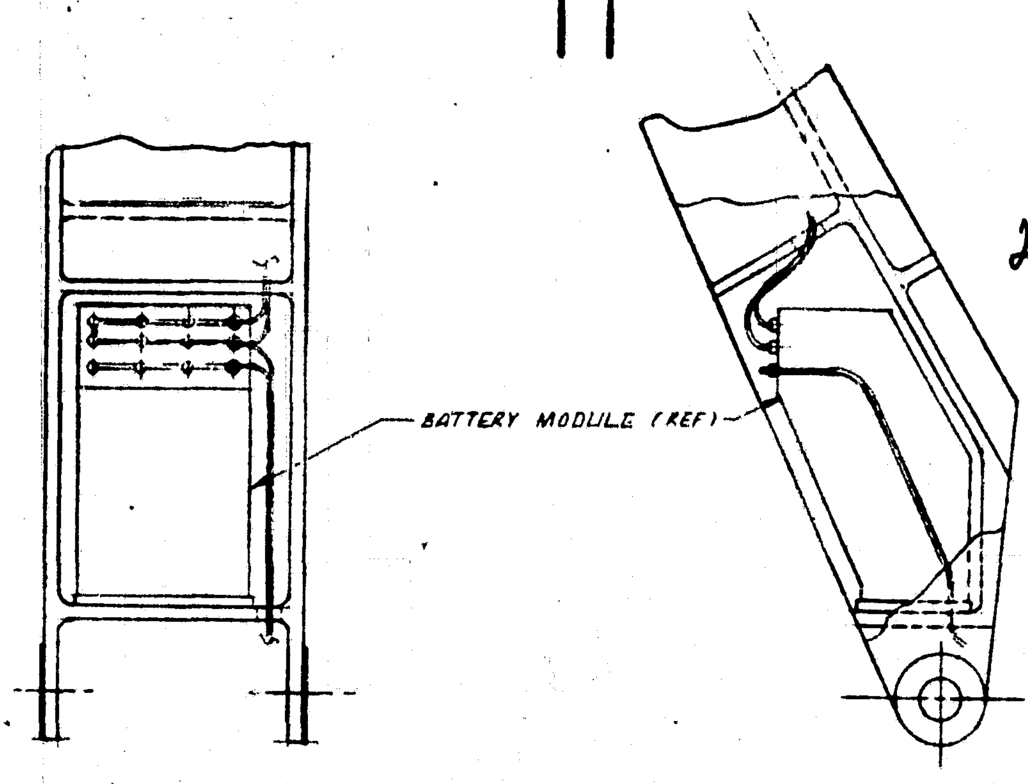
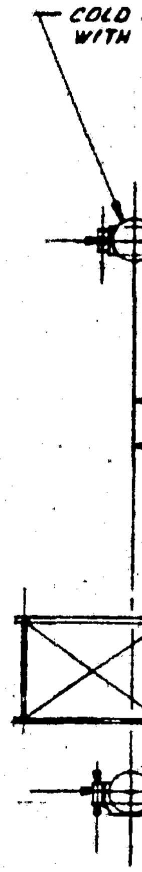


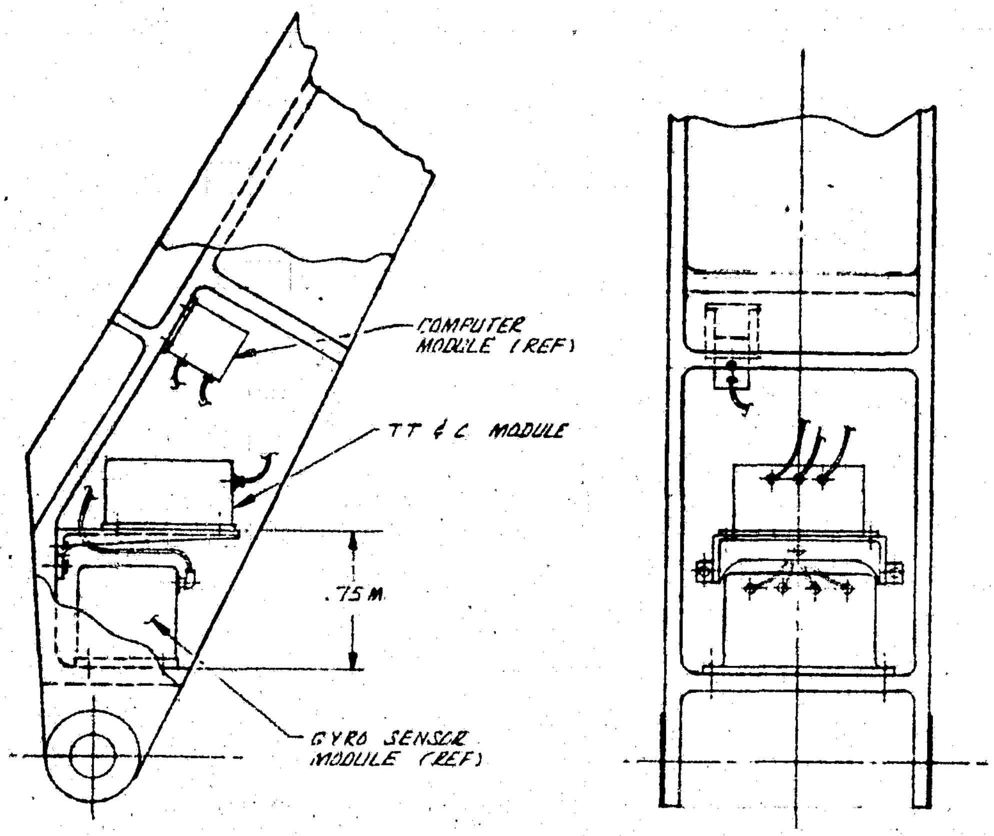
57 | 56 | 55

2) FOLDOUT FRAME



DETAIL VIEW D

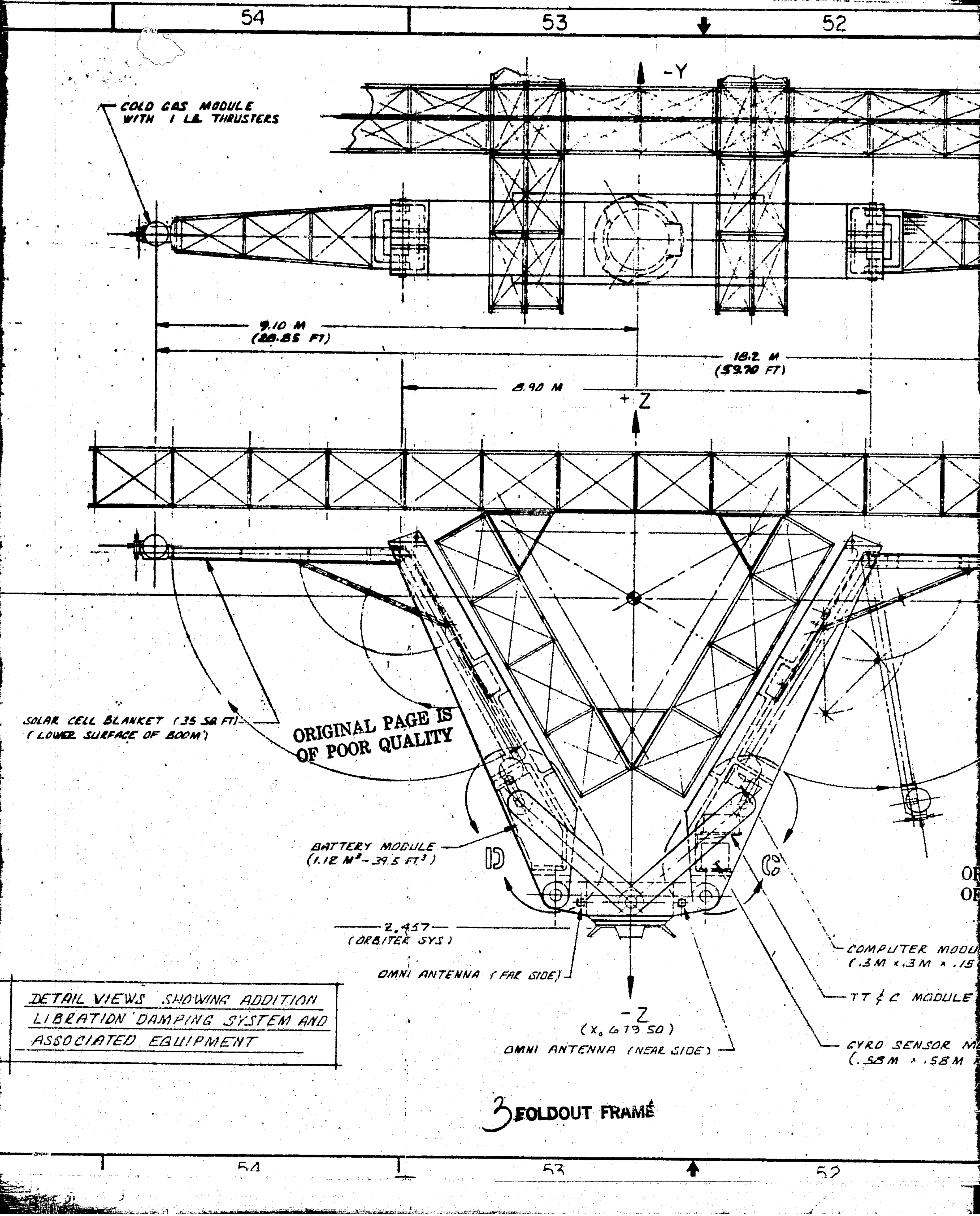




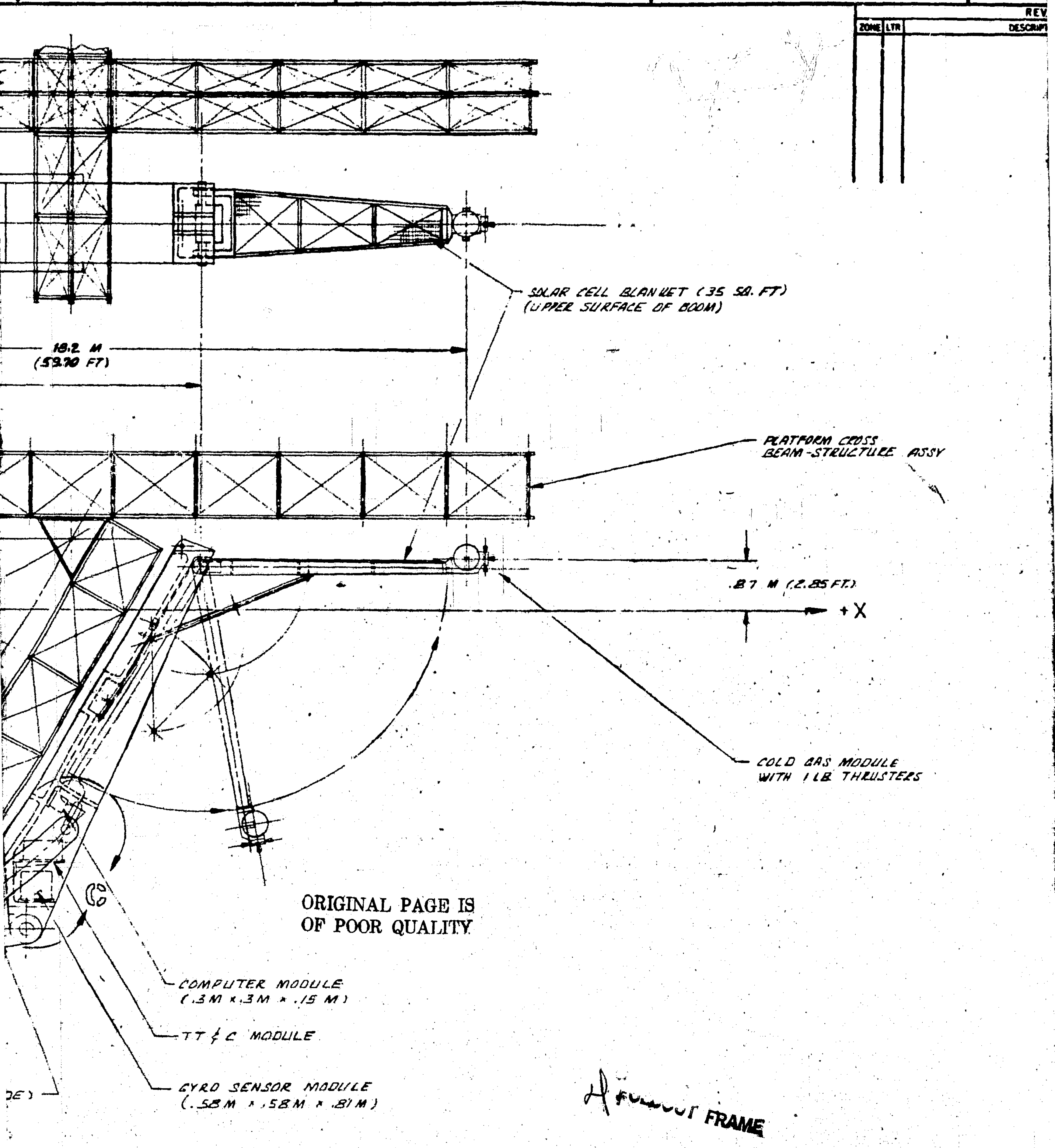
DETAIL VIEW C

DETAIL VIEWS
LIBRATION DA
ASSOCIATED E

42662-50 | 3



54
53
52
-Y
COLD GAS MODULE WITH 1 LB. THRUSTERS
9.10 M
(28.85 FT)
18.2 M
(59.70 FT)
8.90 M
+Z
SOLAR CELL BLANKET (35 SQ FT)
(LOWER SURFACE OF BOOM)
BATTERY MODULE
(1.12 M³ - 39.5 FT³)
2,457
(ORBITER SYS)
OMNI ANTENNA (FAR SIDE)
-Z
(X₀ 679.50)
OMNI ANTENNA (NEAR SIDE)
COMPUTER MODU
(.3M × .3M × .15
TT & C MODULE
GYRO SENSOR M
(.58M × .58M
DETAIL VIEWS SHOWING ADDITION
LIBRATION DAMPING SYSTEM AND
ASSOCIATED EQUIPMENT



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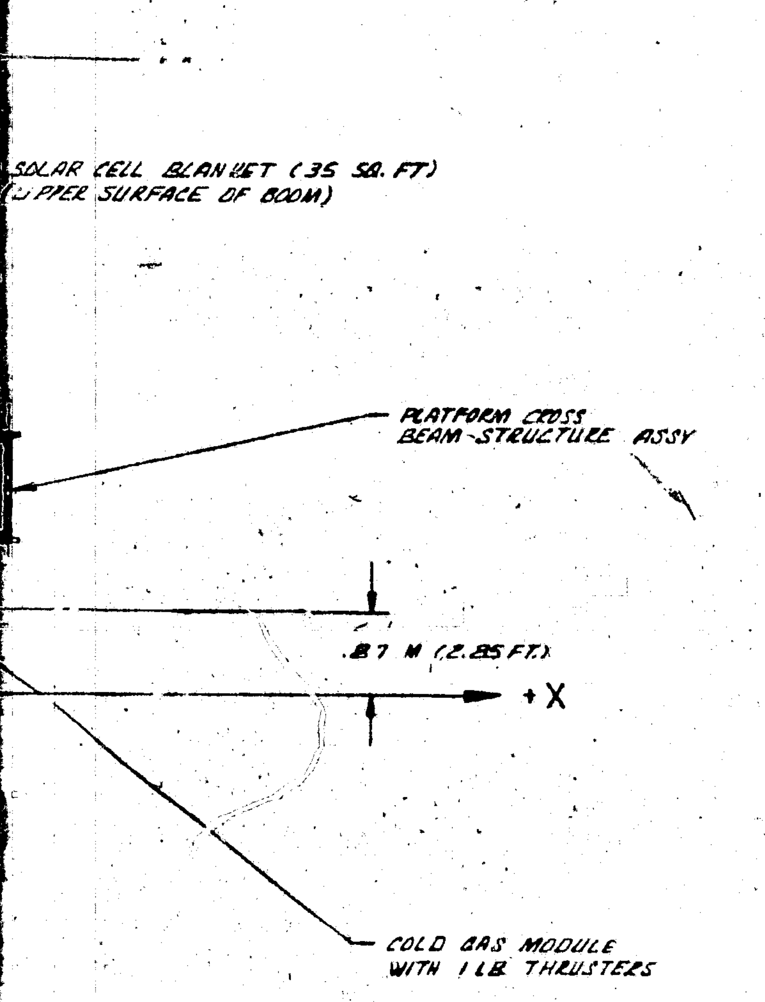
FOLDOUT FRAME

SIZE	CODE IDENT NO.
L	03953

SCALE

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



D
C
B
A

42662-50 3

6
FOLDOUT FRAME

A-11,
A-12

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662-50
SCALE		SHEET 3 OF 4

96 95 94

D

C

B

A

FOLDOUT FRAME

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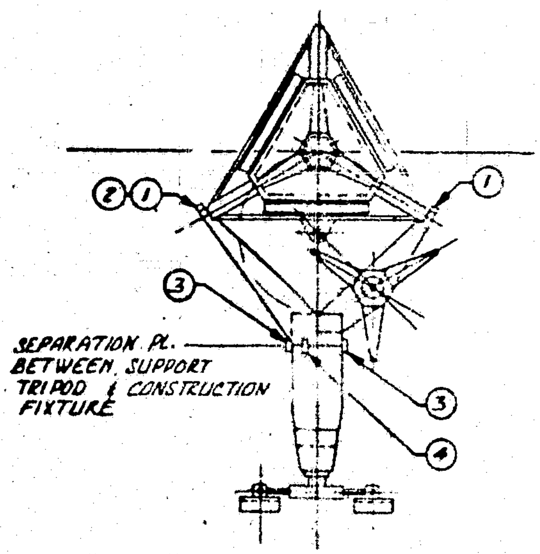
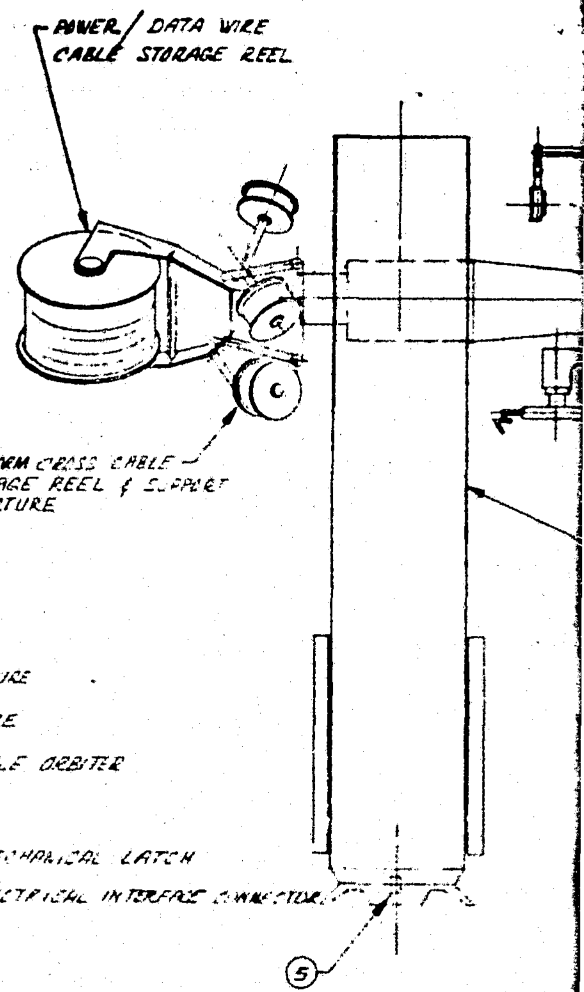




(1) MECHANICAL LATCH BETWEEN BEAM BUILDER AND SUPPORT TRIPOD

(2) ELECTRICAL CONNECTION BETWEEN BEAM BUILDER AND SUPPORT TRIPOD

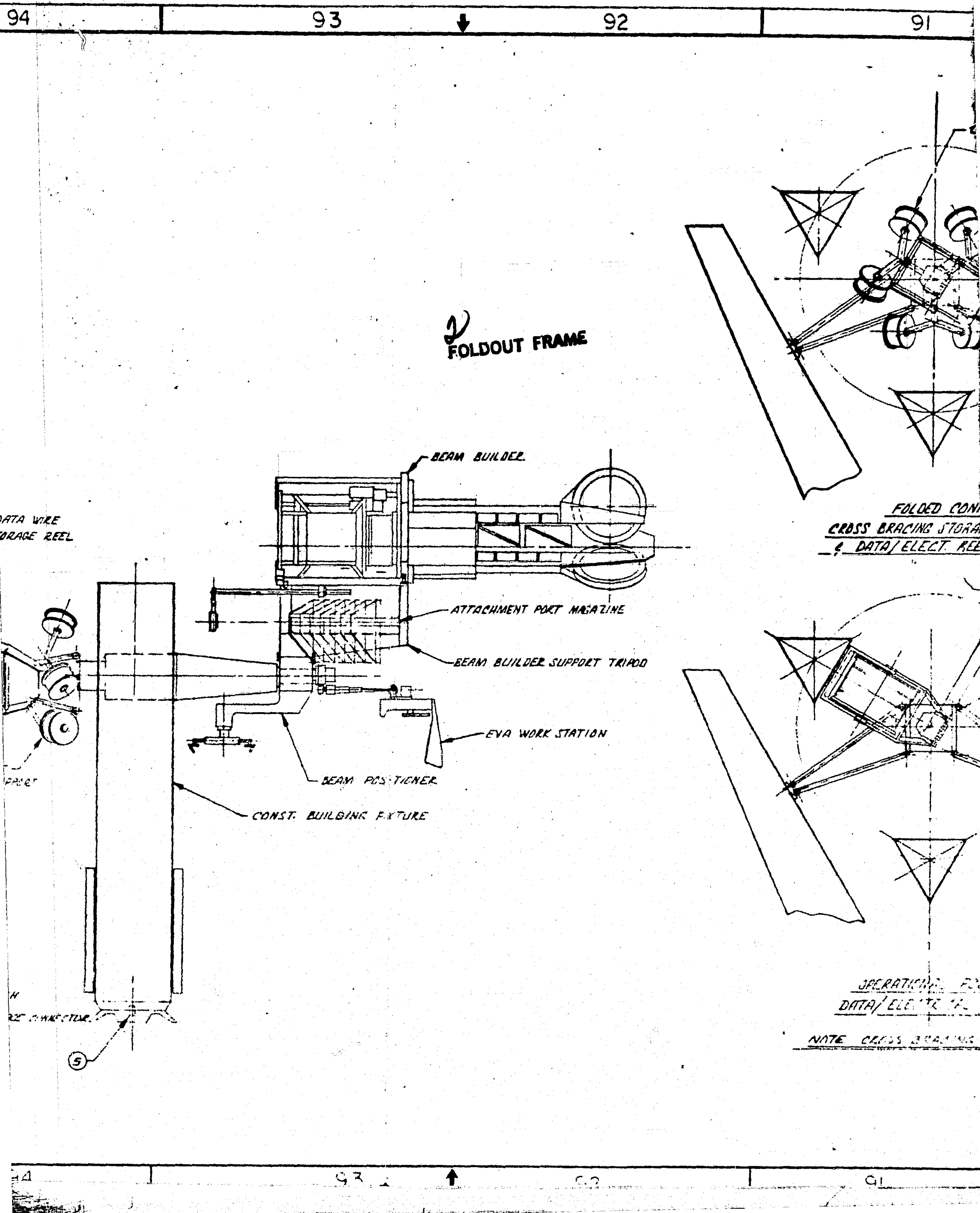
(3) MECHANICAL LATCH BETWEEN SUPPORT TRIPOD AND CONSTRUCTION FIXTURE

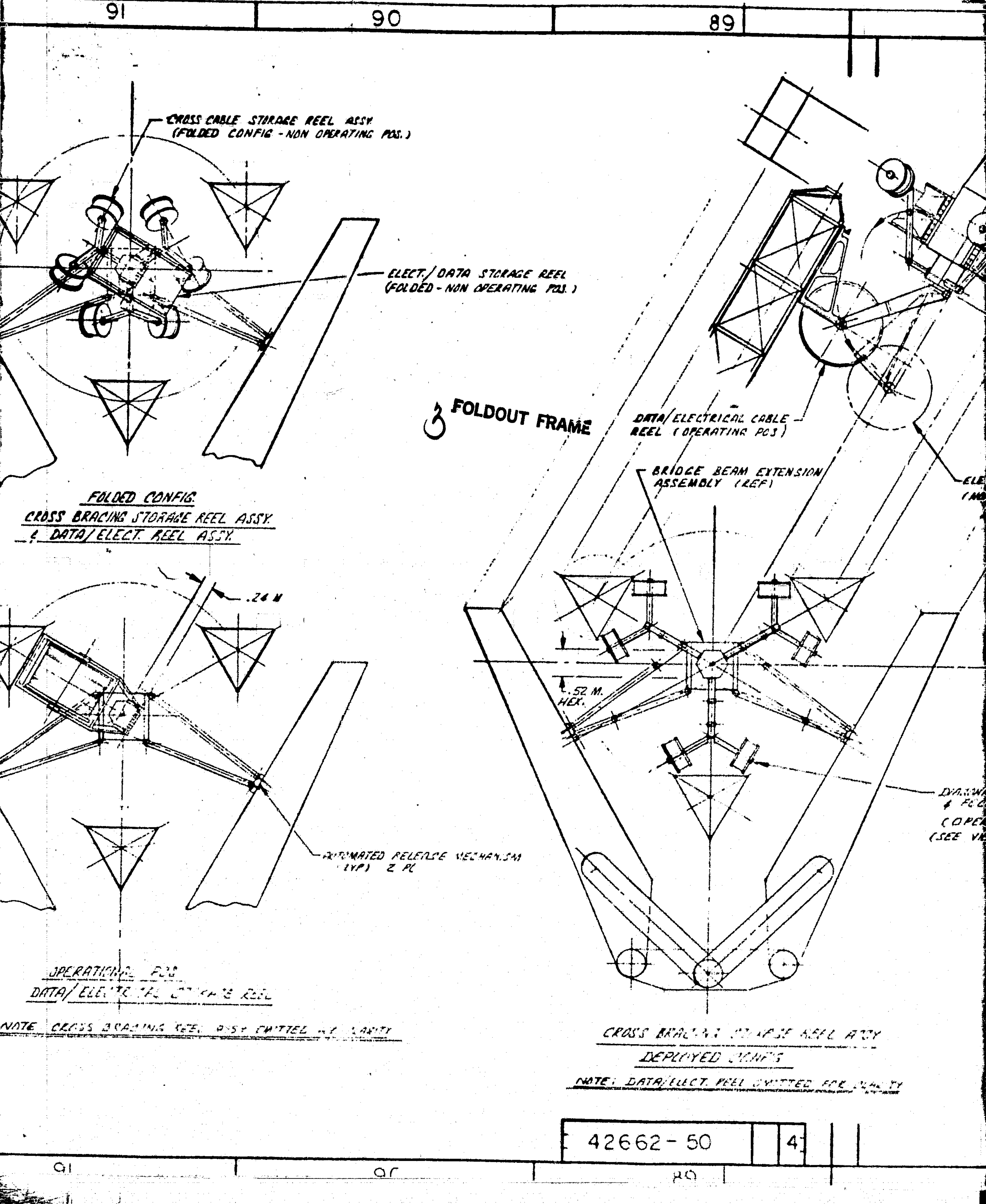
(4) ELECTRICAL CONNECTION BETWEEN SUPPORT TRIPOD AND CONST FIXTURE

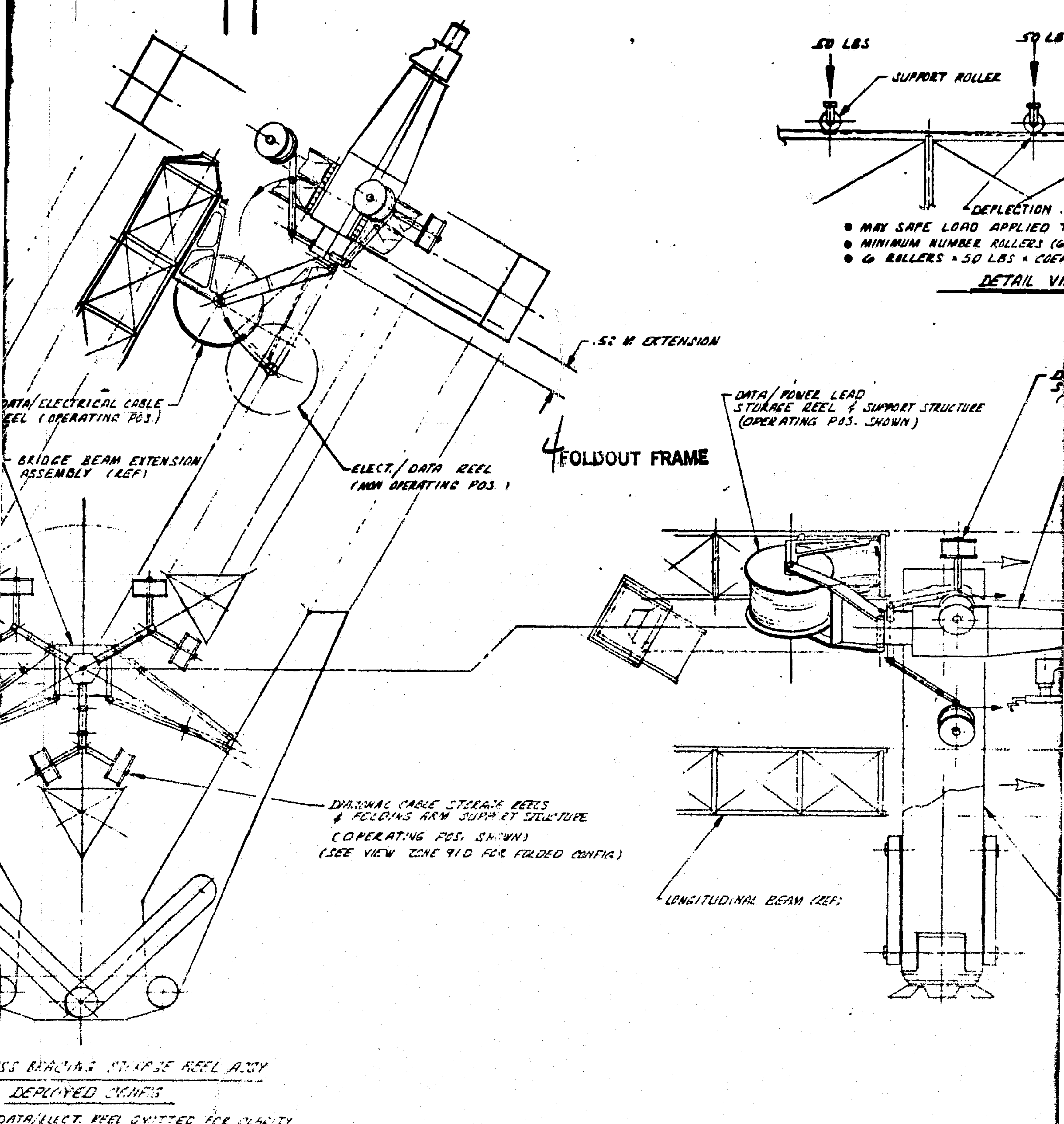
(5) ELECTRICAL CONNECTION BETWEEN BUILDING FIXTURE AND SHUTTLE ORBITER

NOTE:
- SEE DWG 426[illegible] 603 FOR A FUNCTIONALLY SIMILAR MECHANICAL LATCH
- SEE DWG 426[illegible] 70 FOR A FUNCTIONALLY SIMILAR ELECTRICAL INTERFACE CONNECTOR.

FOLDOUT FRAME

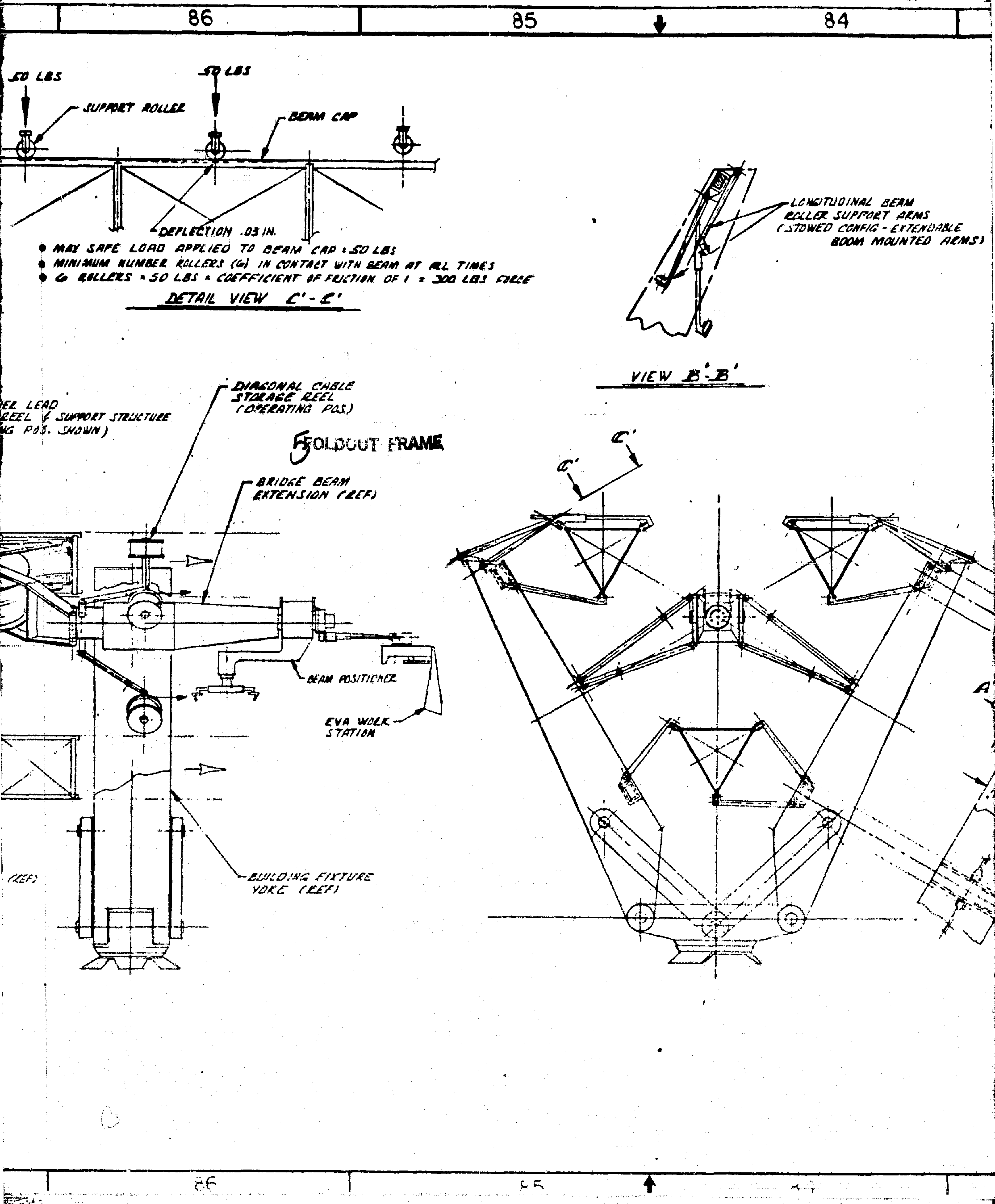



91
90
89
CROSS CABLE STORAGE REEL ASSY
(FOLDED CONFIG - NON OPERATING POS.)
ELECT./DATA STORAGE REEL
(FOLDED - NON OPERATING POS.)
FOLDOUT FRAME
DATA/ELECTRICAL CABLE
REEL (OPERATING POS)
BRIDGE BEAM EXTENSION
ASSEMBLY (REF)
FOLDED CONFIG.
CROSS BRACING STORAGE REEL ASSY.
& DATA/ELECT. REEL ASSY.
.24 M
.52 M.
HEX.
AUTOMATED RELEASE MECHANISM
(TYP) 2 PL
DEPLOYED CONFIG
42662-50
4

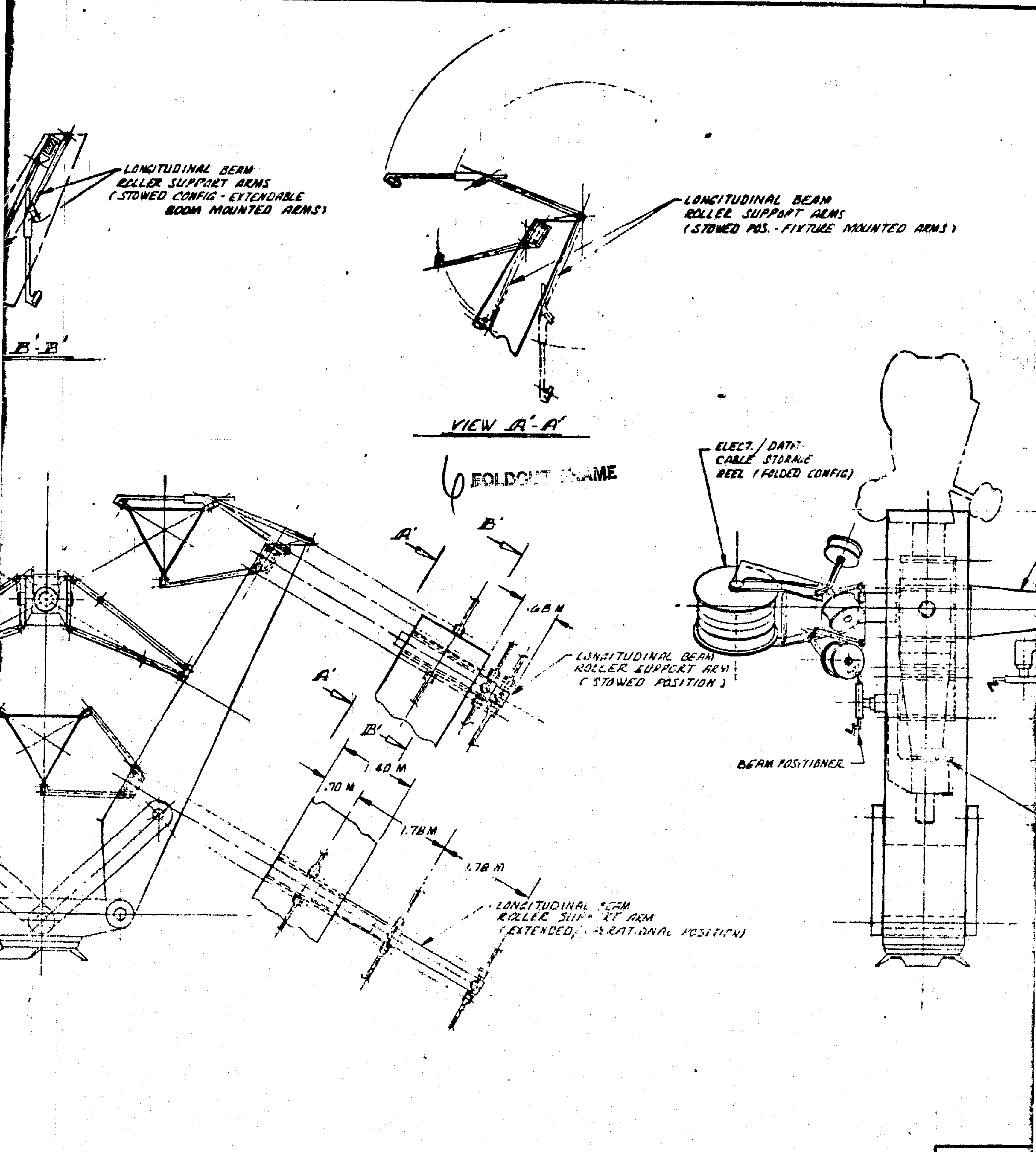


FOLDOUT FRAME

62-50 | 4



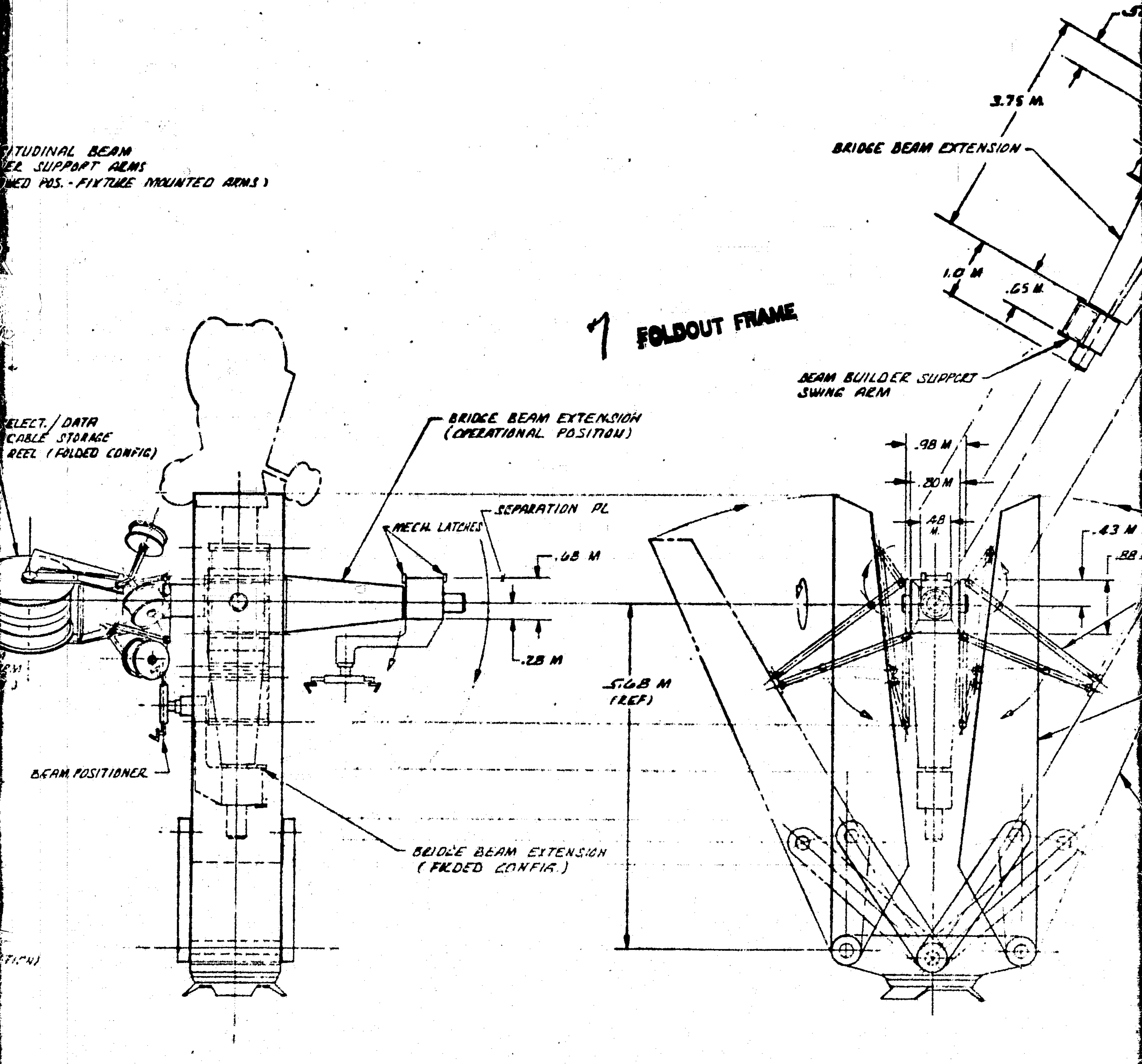
86
85
84
50 LBS
50 LBS
SUPPORT ROLLER
BEAM CAP
DEFLECTION .03 IN.
• MAX SAFE LOAD APPLIED TO BEAM CAP = 50 LBS
• MINIMUM NUMBER ROLLERS (6) IN CONTACT WITH BEAM AT ALL TIMES
• 6 ROLLERS × 50 LBS × COEFFICIENT OF FRICTION OF 1 = 300 LBS FORCE
DETAIL VIEW C'-C'
LONGITUDINAL BEAM ROLLER SUPPORT ARMS (STOWED CONFIG - EXTENDABLE BOOM MOUNTED ARMS)
VIEW B'-B'
DIAGONAL CABLE STORAGE REEL (OPERATING POS)
EL LEAD
REEL & SUPPORT STRUCTURE
NG POS. SHOWN)
FOLDOUT FRAME
C'
C'
BRIDGE BEAM EXTENSION (REF)
BEAM POSITIONER
EVA WORK STATION
BUILDING FIXTURE YOKE (REF)
(REF)
A
86
85
84

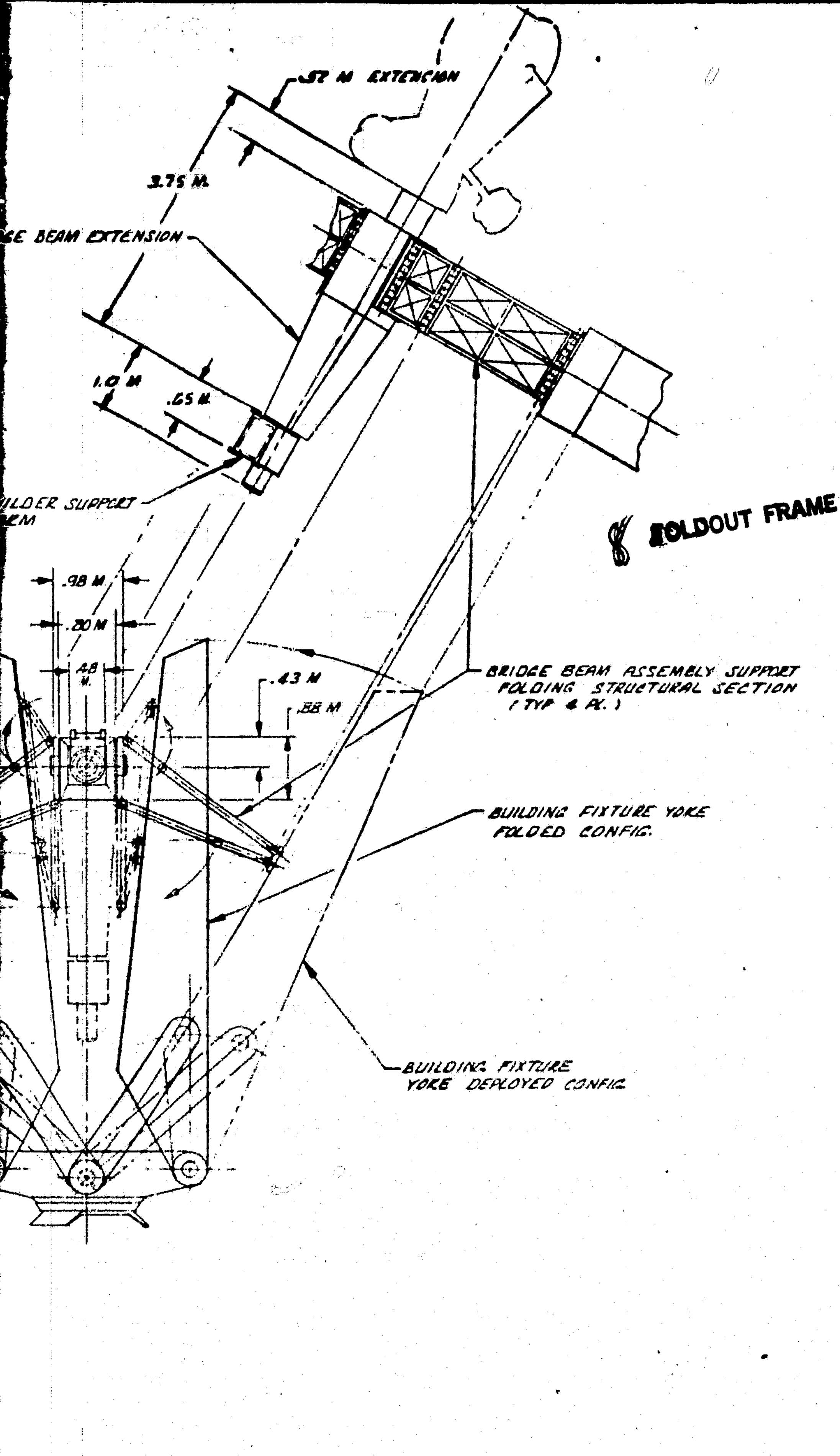


FOLDOUT FRAME

4266

FOLDOUT FRAME





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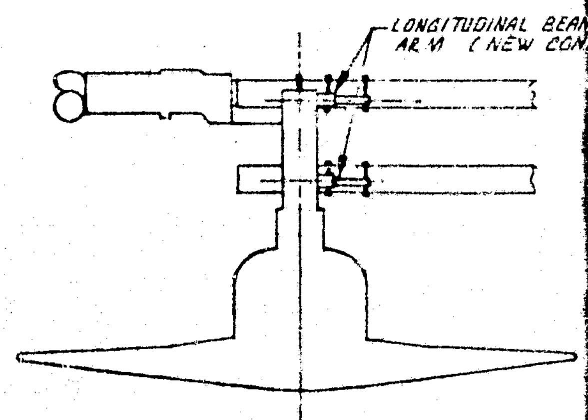

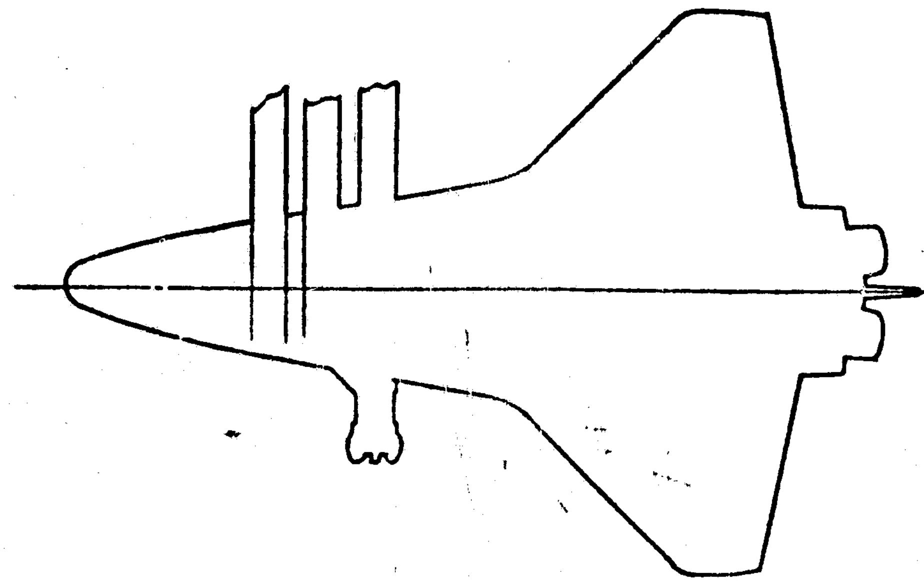

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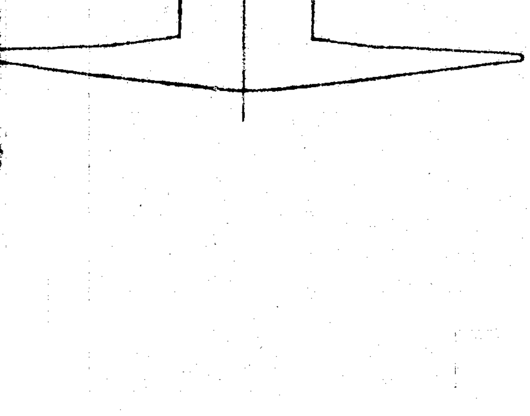
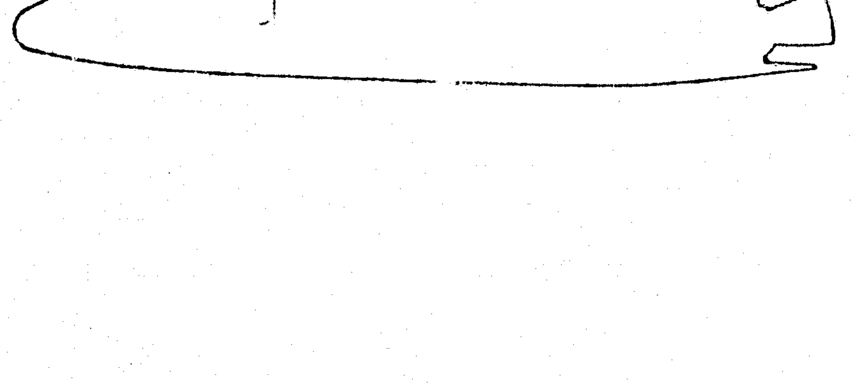
FOLDOUT FRAME

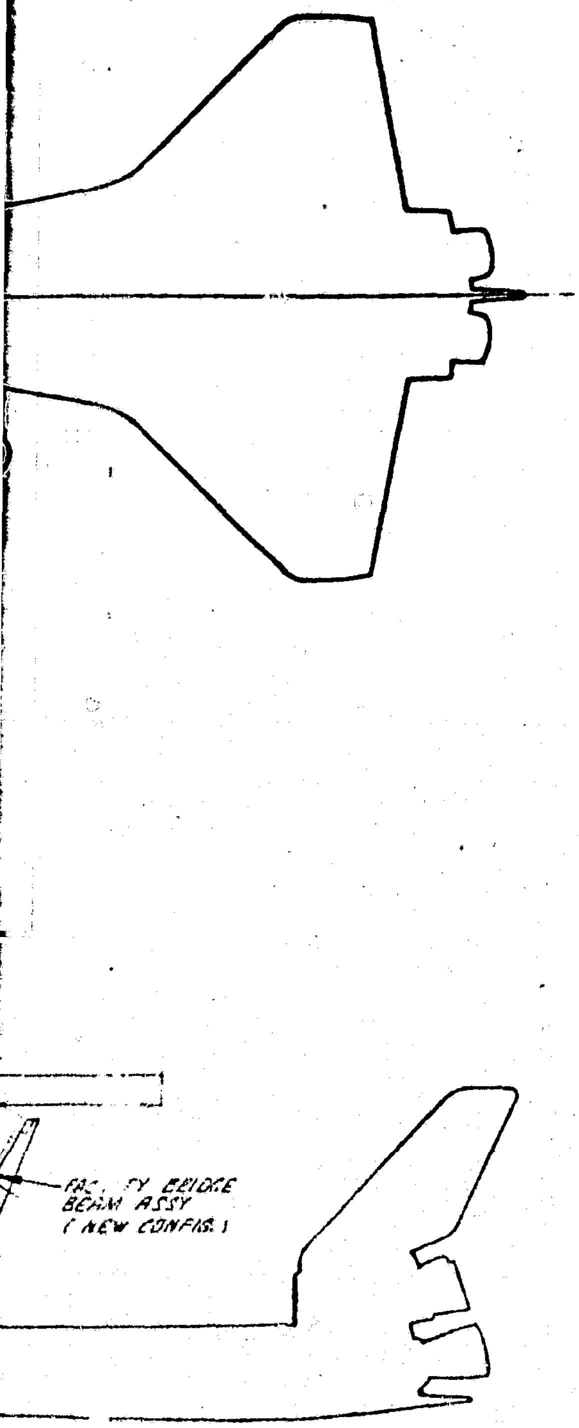




75 | 74 | 73

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

D



C

DETAIL VIEWS SHOWING REDESIGN OF:

- BRIDGE BEAM STRUCTURE ASSY.
- LONGITUDINAL BEAM ROLLER SUPPORT ARM ASSEMBLIES
- DATA/POWER LEAD STORAGE REEL ASSY. & INSTALLATION
- CROSS BRACE WIRE STORAGE REELS AND ASSOCIATED SUPPORT MECHANISM
- BEAM MACHINE ASSEMBLY CONFIG.

B

4

42562-50

10

FOLDOUT FRAME

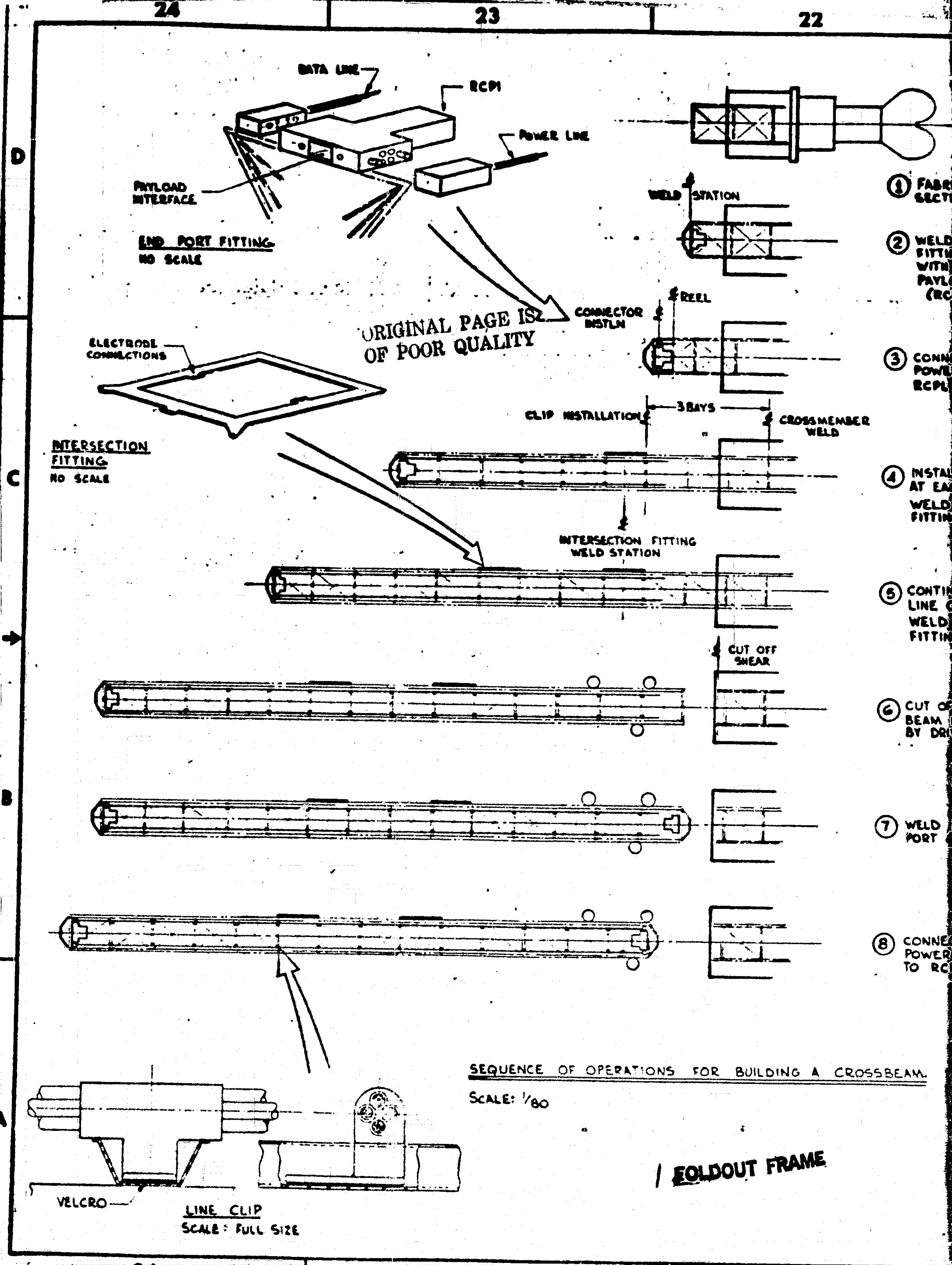
A-13,
A-14

A

SIZE	CODE IDENT NO	DRAWING NO
L	03953	42562-50

SCALE | | SHEET 4

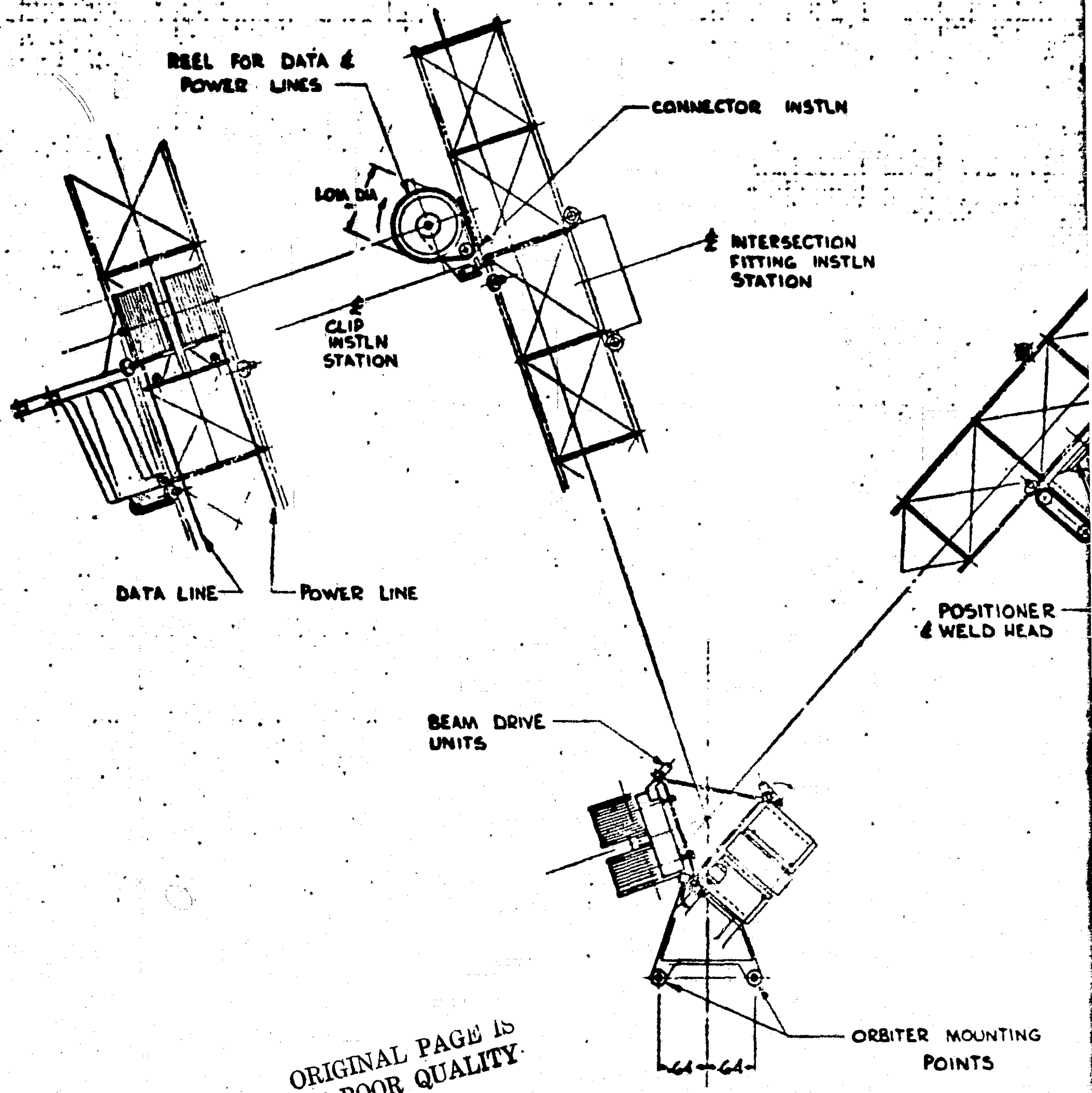
75 | 74 | 73



SEQUENCE OF OPERATIONS FOR BUILDING A CROSSBEAM.

SCALE: 1/80

1. FABRICATE SHORT SECTION OF BEAM.
2. WELD END PORT FITTING, COMPLETE WITH REMOTE CONTROL PAYLOAD INTERFACE. (RCPI)
3. CONNECT DATA & POWER LINES TO RCPI.
4. INSTALL LINE CLIPS AT EACH CROSSMEMBER. WELD INTERSECTION FITTING.
5. CONTINUE TO INSTALL LINE CLIPS. WELD 2nd INTERSECTION FITTING.
6. CUT OFF BEAM. BEAM IS SUPPORTED BY DRIVE ROLLERS.
7. WELD 2nd END PORT & RCPI
8. CONNECT DATA & POWER LINES TO RCPI.



VIEW BB

SCALE: 1/40

5BEAM.

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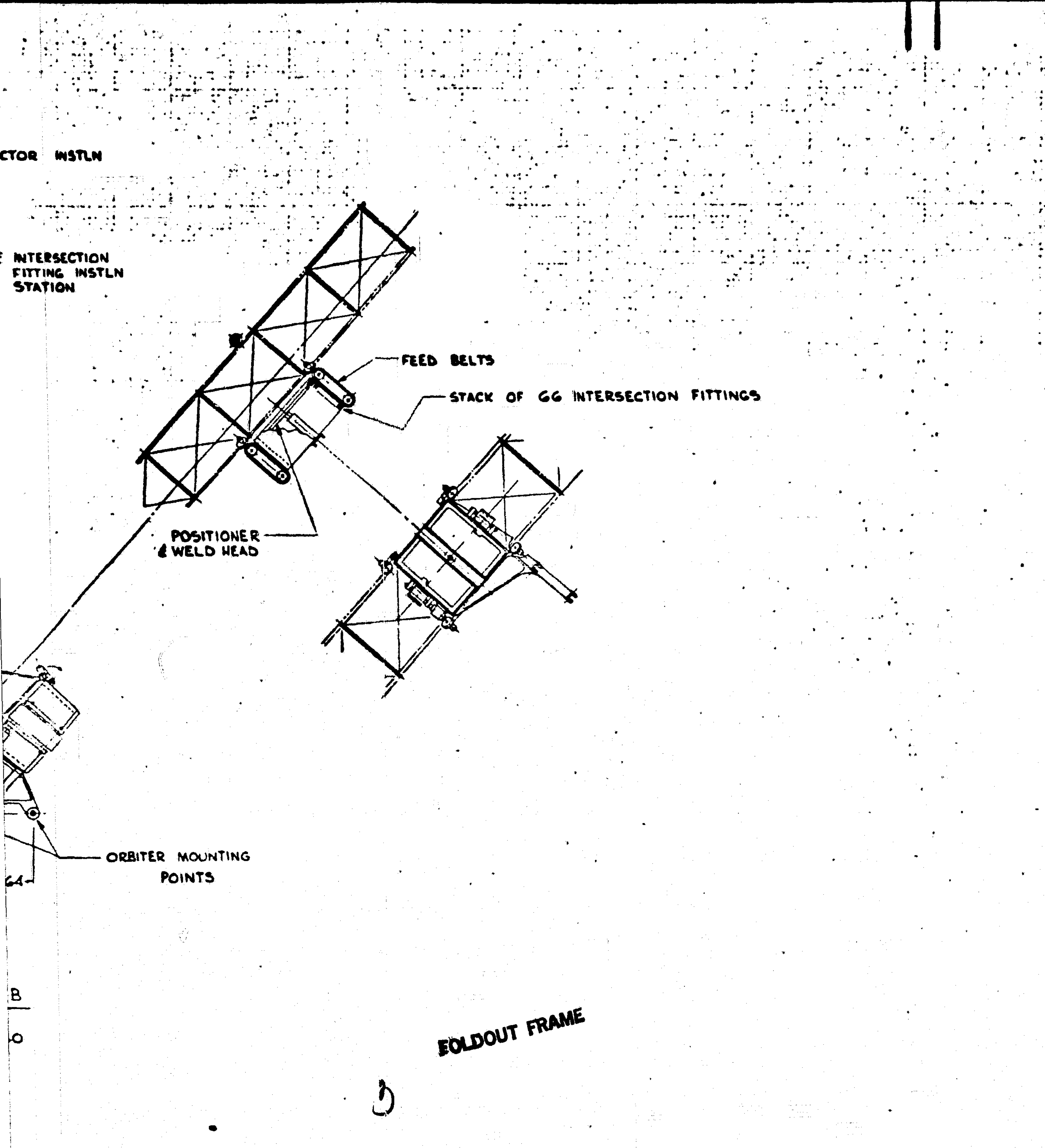
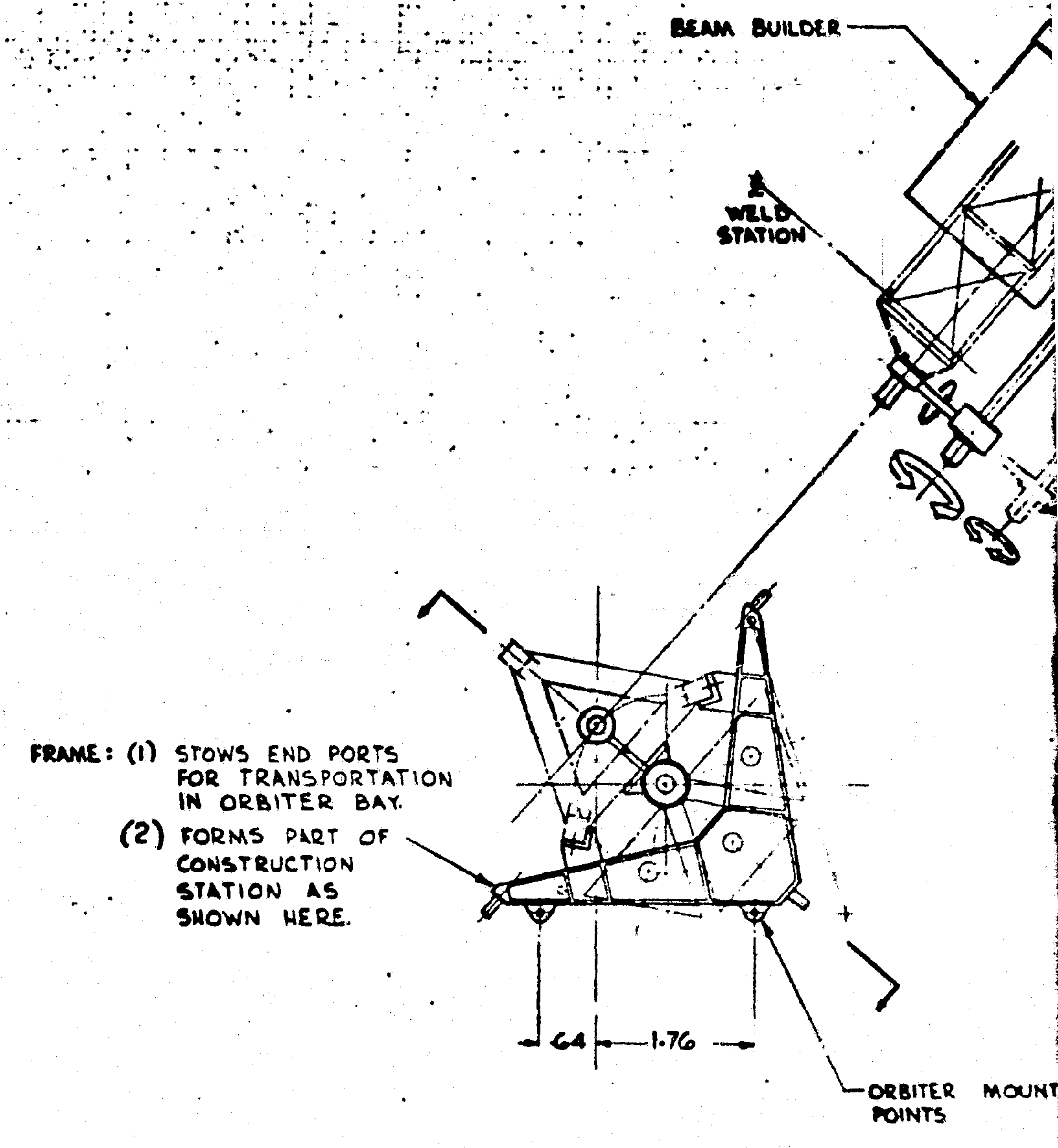
FOLDOUT FRAME 2



FOLDOUT FRAME

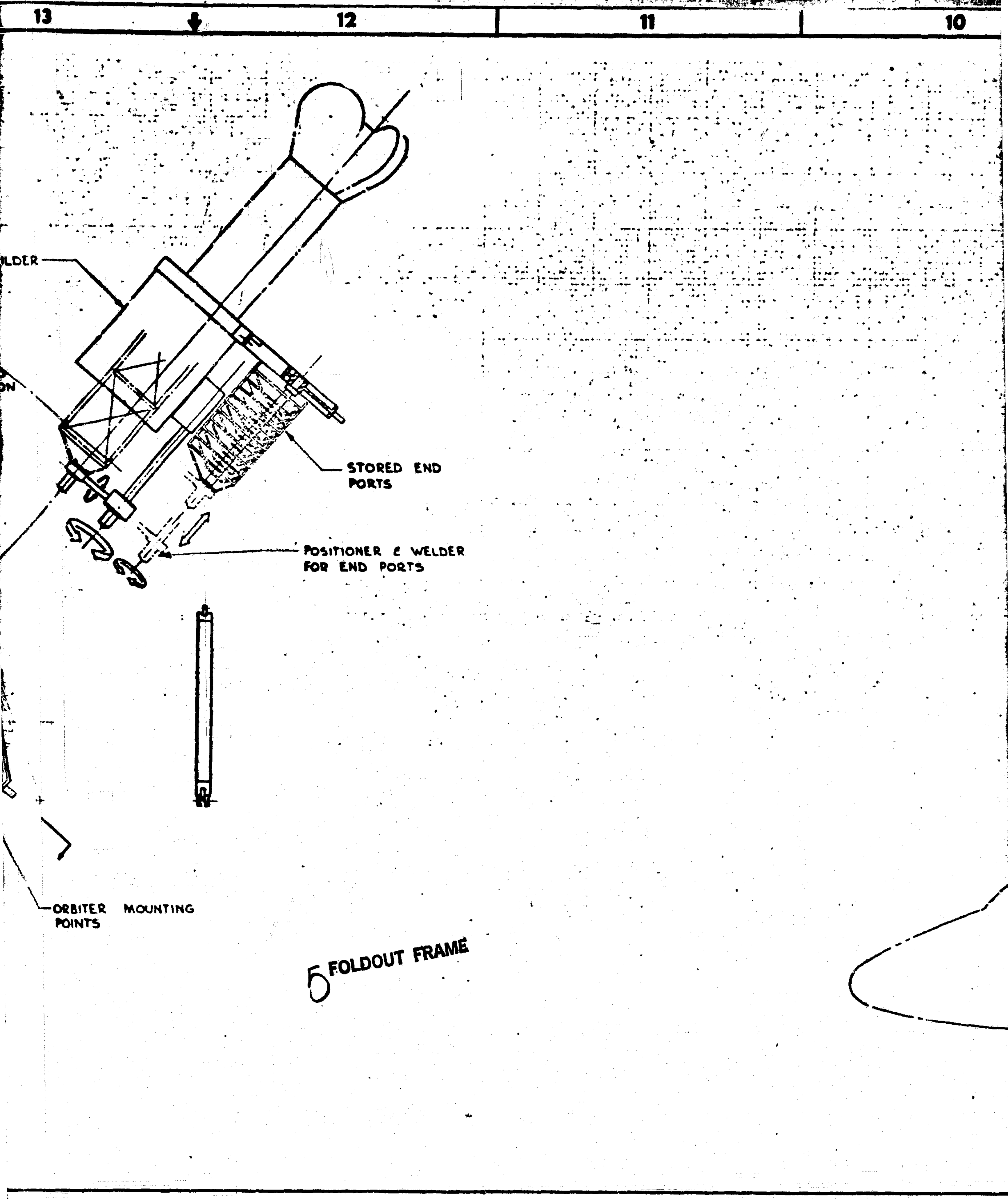
	15	14	13



VIEW AA

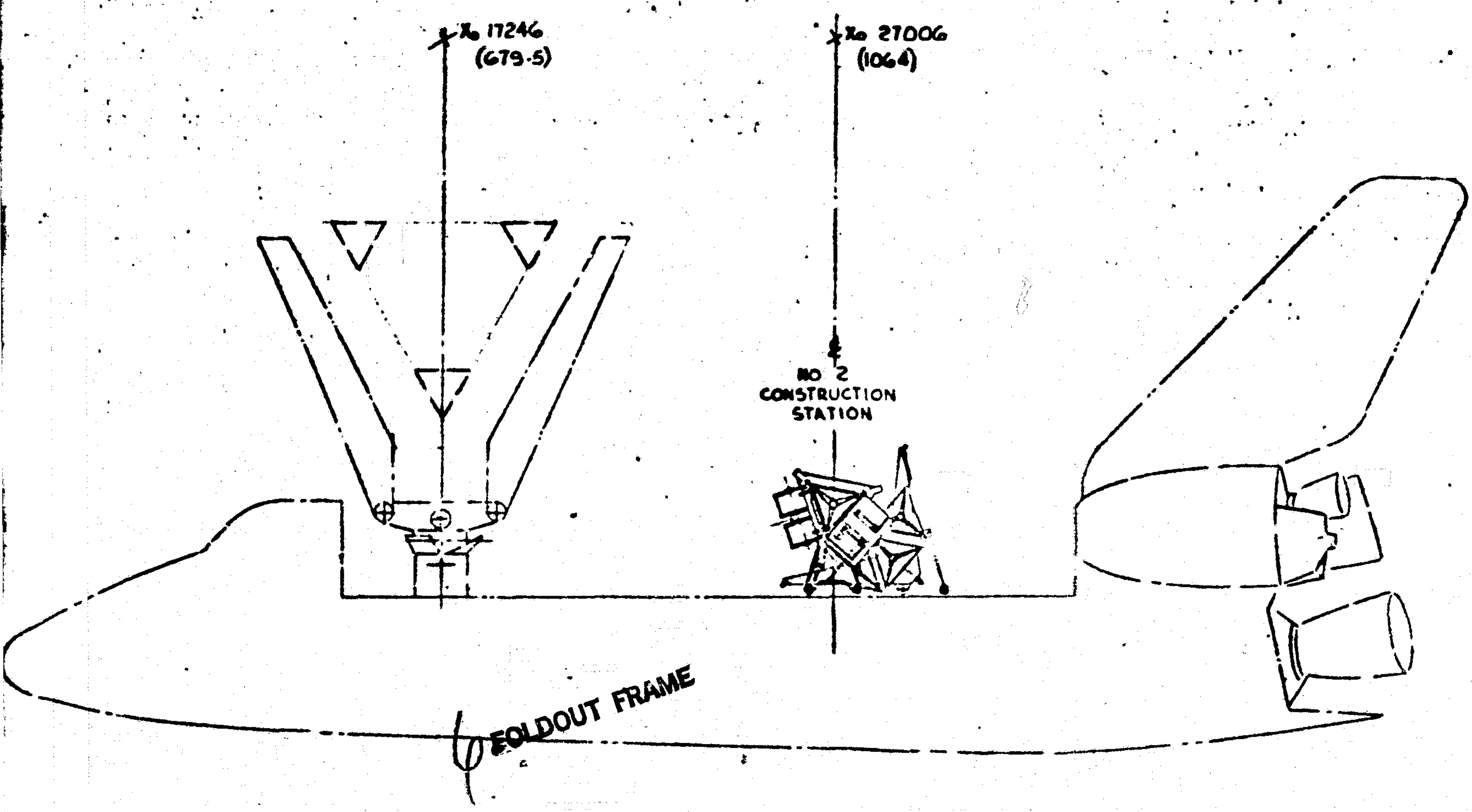
SCALE: 1/40

FOLDOUT FRAME



5 FOLDOUT FRAME

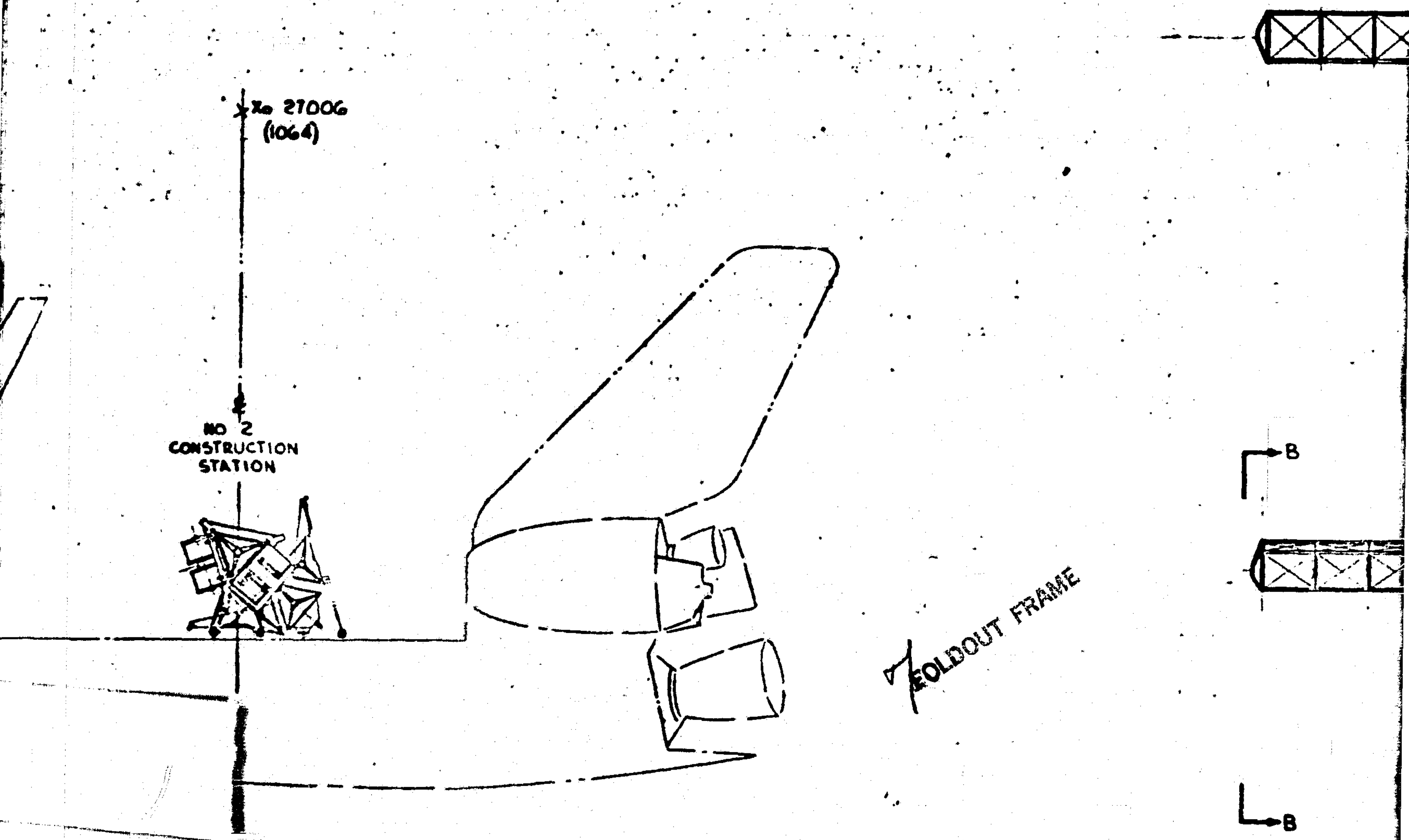
10	9	8



FOLDOUT FRAME

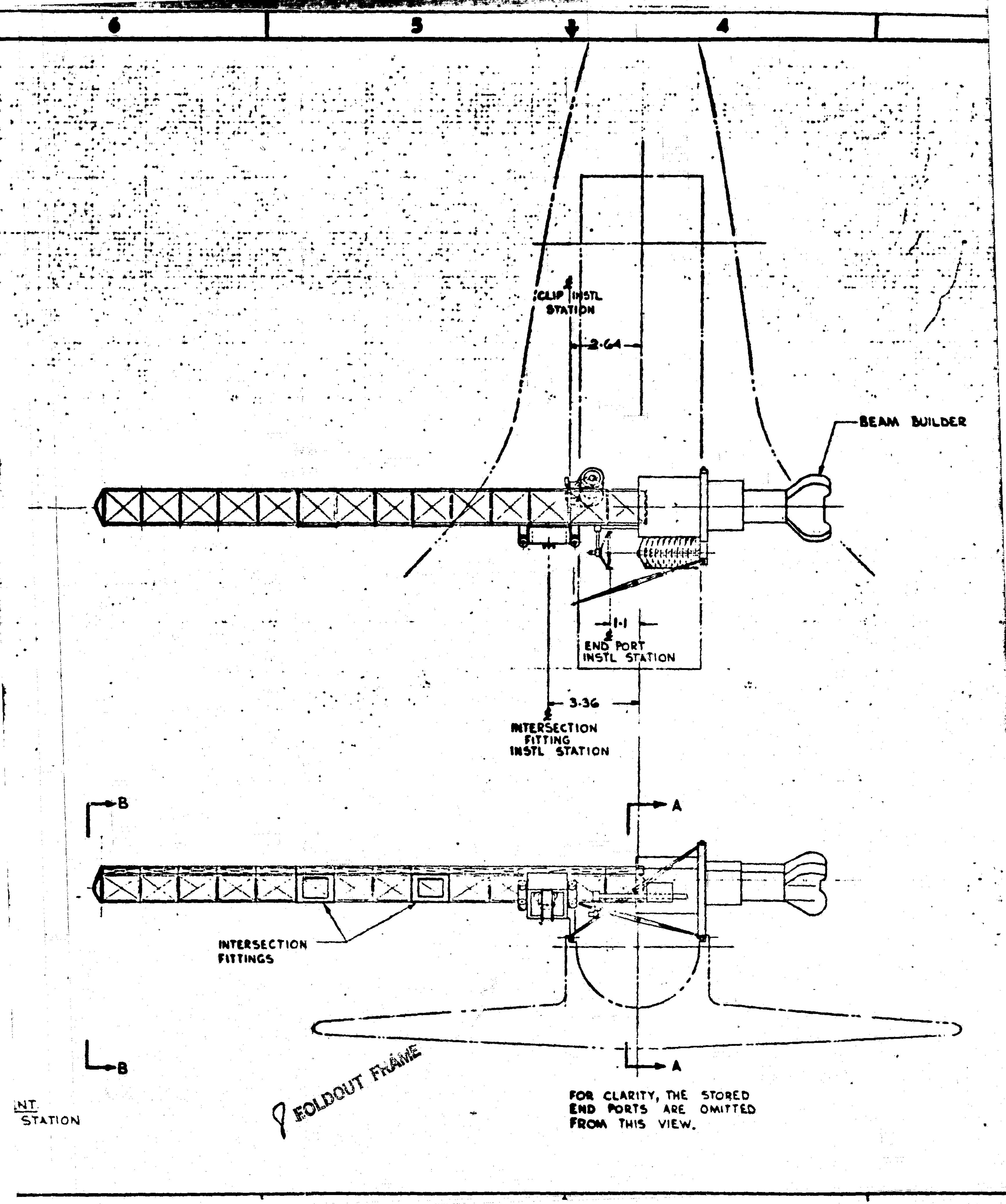
42662-52 SH 1

8 7 6



GENERAL ARRANGEMENT
NO 2 CONSTRUCTION STATION
SCALE: 1/80

52 SH 1



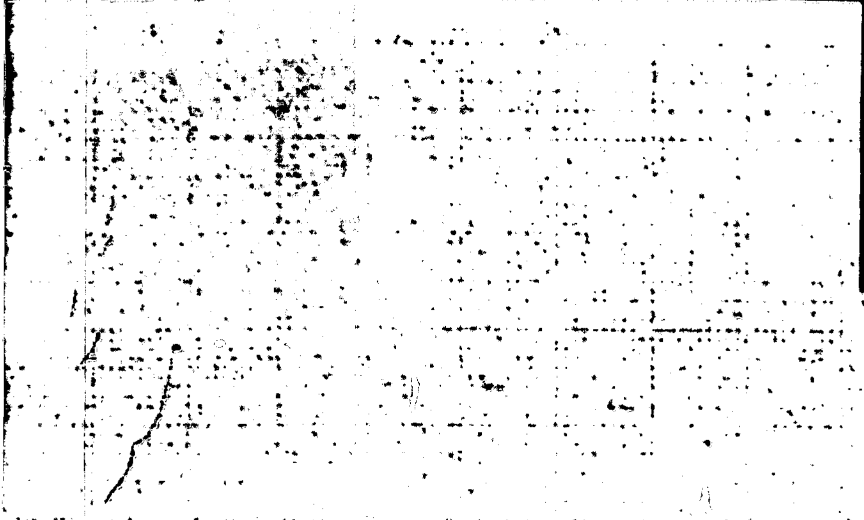
FOLDOUT FRAME

3 | 2 | 1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
		SEE SHEET 2 FOR DESIGN CHANGES MADE AS A RESULT OF THE ERB BRIEFING ENTITLED "SETTING UP NO2 WORK STATION EVA vs NON EVA" DATED 1NOV 1979	2 NOV 1979 R J HART	

D



BEAM BUILDER

C

B

9 FOLDOUT FRAME

42662 -52

A-15,
A-16

7

DR BY	R HART	OCT 79
CHK BY		
APPROVED BY		

Rockwell International Corporation
Space Division
12214 Lakewood Boulevard • Downey, California 90241

NO 2 CONSTRUCTION STATION
APPLICATIONS TECHNOLOGY PLATFORM

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662 - 52

SCALE NOTED SHEET 1 OF 3

8	7	6

DESIGN CHANGES 2ND ITERATION

Y FRAME

STRUT DELETED.

ADDED INTEGRAL LEG.

Y FRAME SUPPORTED ON ORBITER LONGERONS
AT 3 POINTS USING PAYLOAD RETENTION LATCHES:

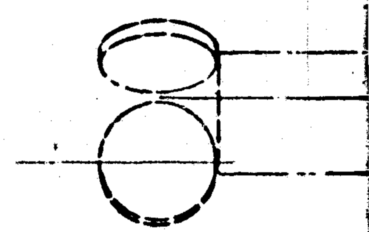
RH @ Xo 25733 FIXED IN XYZ AXES.
RH @ Xo 28133 FIXED IN Y & Z, FLOATING IN X AXIS.
LH @ Xo 25733 FIXED IN Z, FLOATING X & Z AXES.

1 BEAM BUILDER ATTACHED TO Y FRAME AT 3 POINTS WITH REMOTE CONTROL SELF ALIGNING LATCHES.

REMOTE CONTROL ELECTRICAL CONNECTIONS (SIMILAR TO PAYLOAD INTERFACE) BETWEEN:

2 LONGERON & Y FRAME.
3 Y FRAME & BEAM BUILDER.
4 Y FRAME & REEL ASSY.

ADDED EVA WORK STATIONS AT POSITIONS SHOWN WITH TRANSFER HANDRAILS IN BETWEEN.



REEL ASSY

REPOSITIONED THE CABLE REEL.

REEL ASSY FRAME SUPPORTED AT TWO MOUNTING POINTS:

LH LONGERON @ Xo 27013 USING A PAYLOAD RETENTION LATCH FIXED IN Z FLOATING IN X & Y AXES.

FIXED TO Y FRAME @ Yo 2387 Xo 25933 WITH REMOTE CONTROL LATCH.

CABLE REEL FOLDS FOR STOWAGE IN ORBITER.

ADDED EVA WORK STATION

FOLDOUT FRAME

8	7	6

	7	6	5

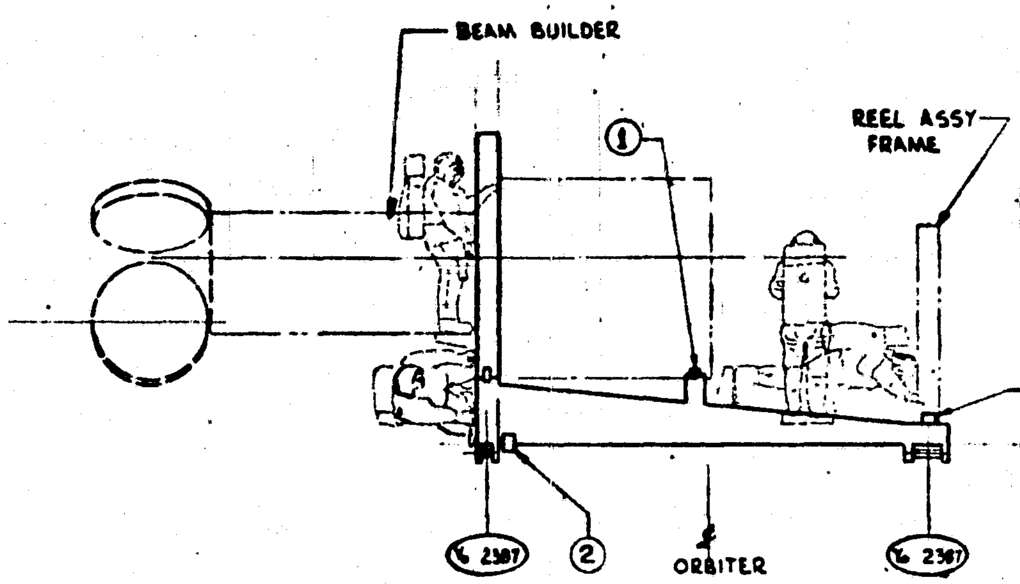
<u>ES 2ND ITERATION</u>

D.
L LEG.
ORTED ON ORBITER LONGERONS
USING PAYLOAD RETENTION LATCHES:
5733 FIXED IN XYZ AXES.
8133 FIXED IN Y & Z, FLOATING IN X AXIS.
5733 FIXED IN Z, FLOATING X & Z AXES.

ATTACHED TO Y FRAME AT 3 POINTS
NTROL SELF ALIGNING LATCHES.

L ELECTRICAL CONNECTIONS (SIMILAR TO
FACE) BETWEEN:
ON & Y FRAME.
E & BEAM BUILDER.
E & REEL ASSY.

ORK STATIONS AT POSITIONS SHOWN
R HANDRAILS IN BETWEEN.



THE CABLE REEL.

AME SUPPORTED AT
POINTS:
N @ Xo 27013 USING A PAYLOAD RETENTION
ED IN Z FLOATING IN X & Y AXES.
Y FRAME @ Yo 2387 Xo 25933
OTE CONTROL LATCH.

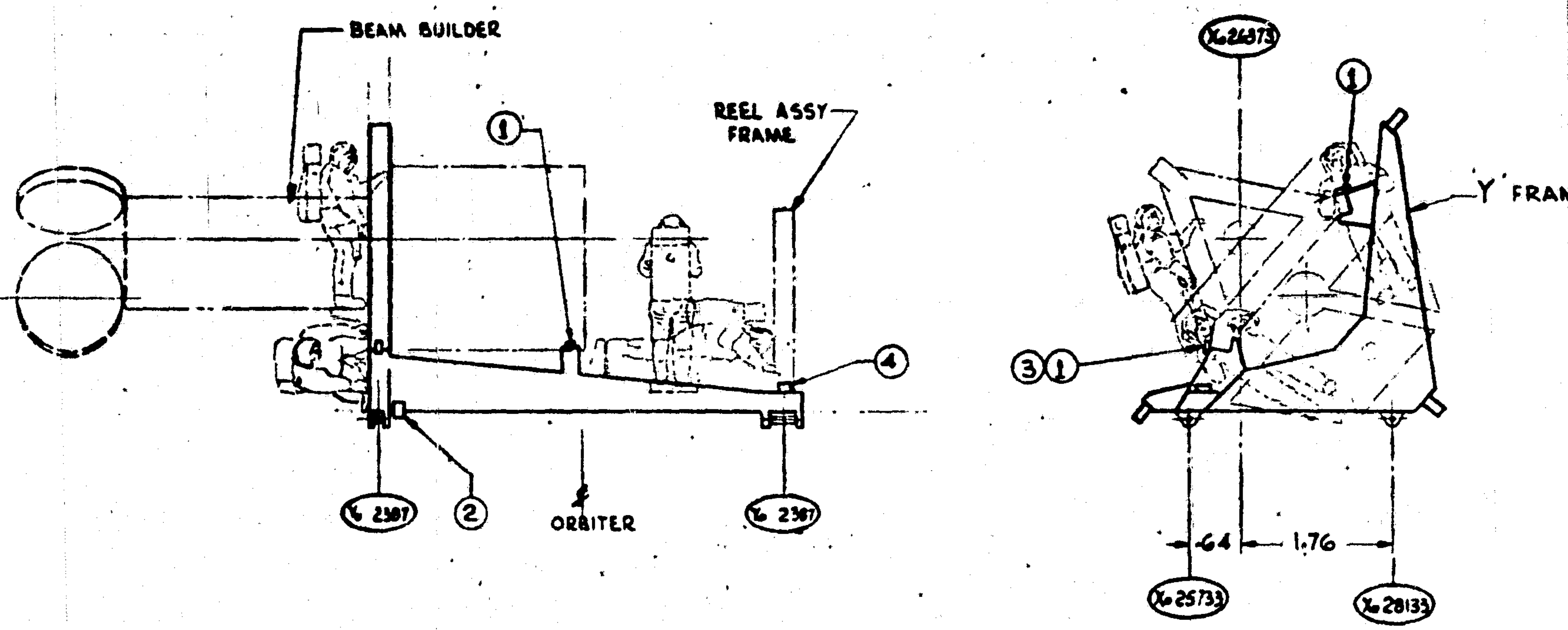
FOLDS FOR STOWAGE IN ORBITER.
ORK STATION

<u>VIEWS SHOWING CHA</u>
<u>Y FRAME</u>
SCALE: 1/40

2 FOLDOUT FRAME

	7	6	5

6 5 4

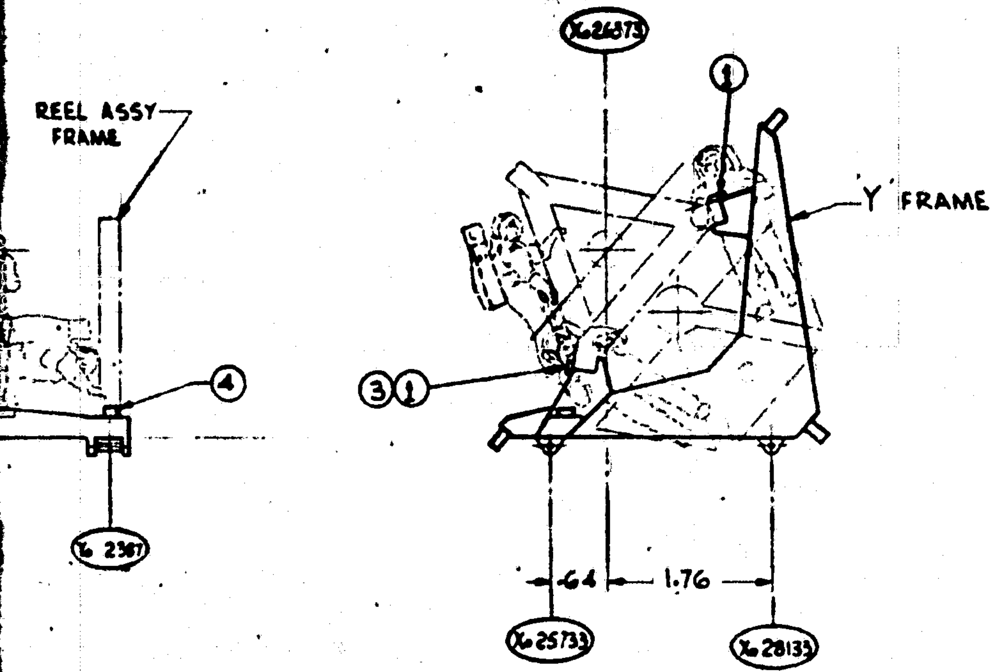


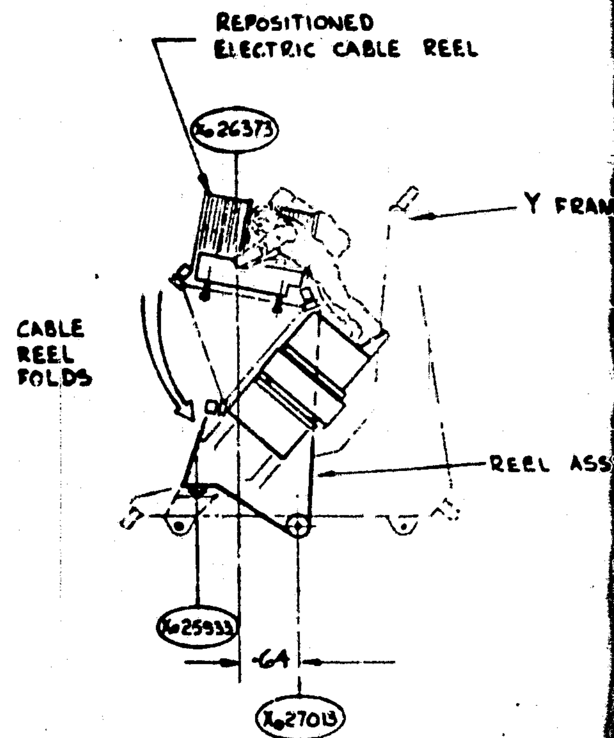
VIEWS SHOWING CHANGES TO
Y FRAME

SCALE: 1/40

3 FOLDOUT FRAME

4 3 2





VIEW SHOWING CHANGES TO REEL ASSY & FRAME

SCALE: 1/40.

SHOWING CHANGES TO
Y FRAME

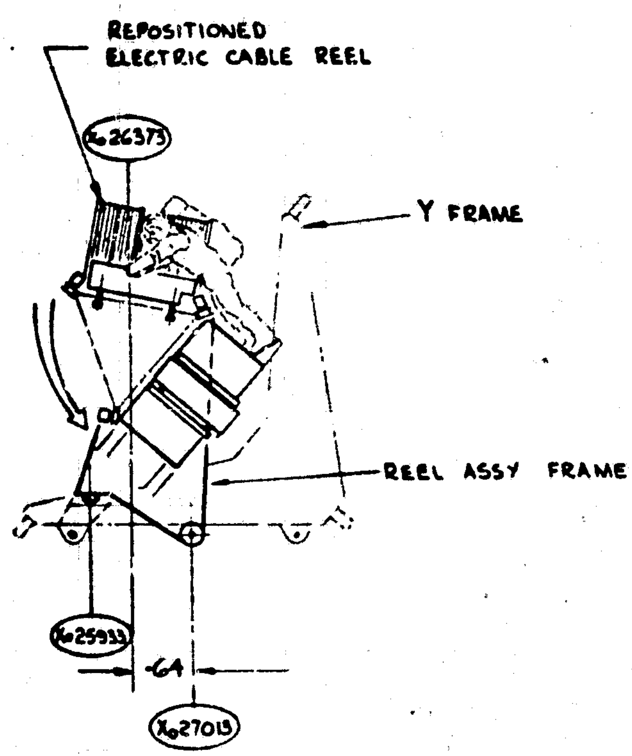
ALE:

4 FOLDOUT FRAME

DR BY	R HART	NOV 73
CHK BY		
APPROVED BY		

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

Y FRAME



VIEW SHOWING CHANGES TO REEL ASSY & FRAME

SCALE: 1/40

5

FOLDOUT FRAME

A-17,
A-18

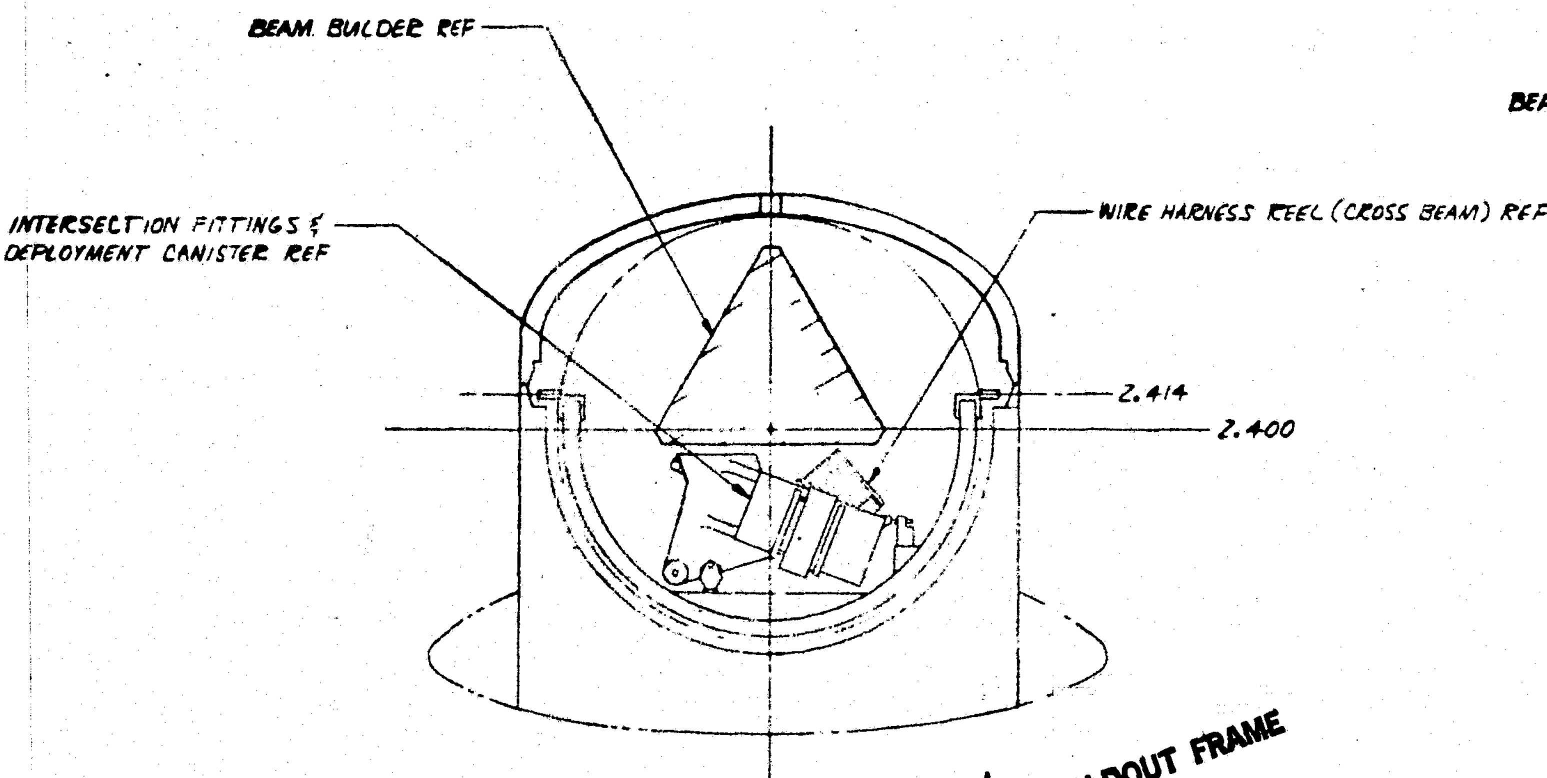
Rockwell International Corporation
Space Division
12214 Lakewood Boulevard • Downey, California 90241

R HART	NOV 75
CHK BY	
APPROVED BY	

NO 2 CONSTRUCTION STATION
ENG TECH & VERIFICATION PLATFORM

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662 52

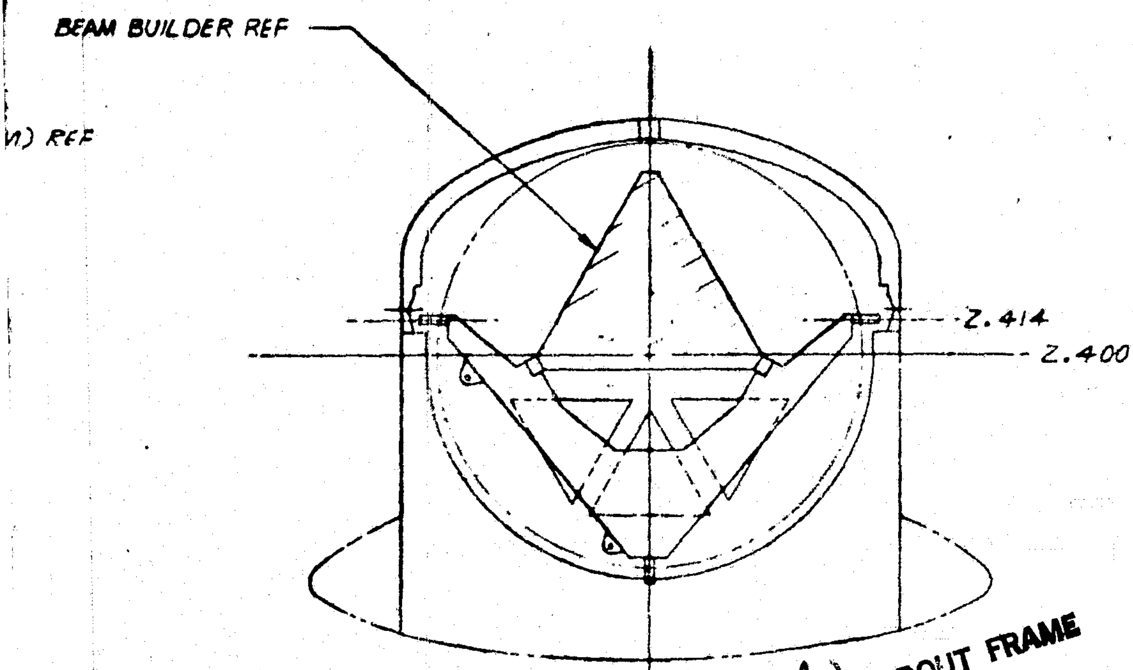
SCALE NOTED — SHEET 2 OF 2



SECTION D-D

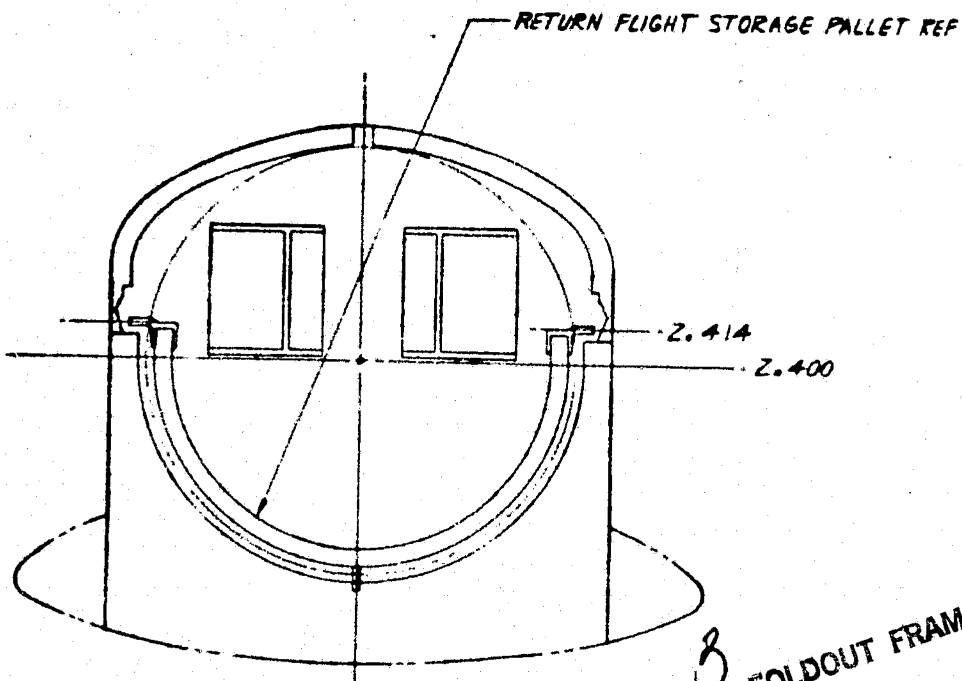
BEAM BUILD

FOLDOUT FRAME



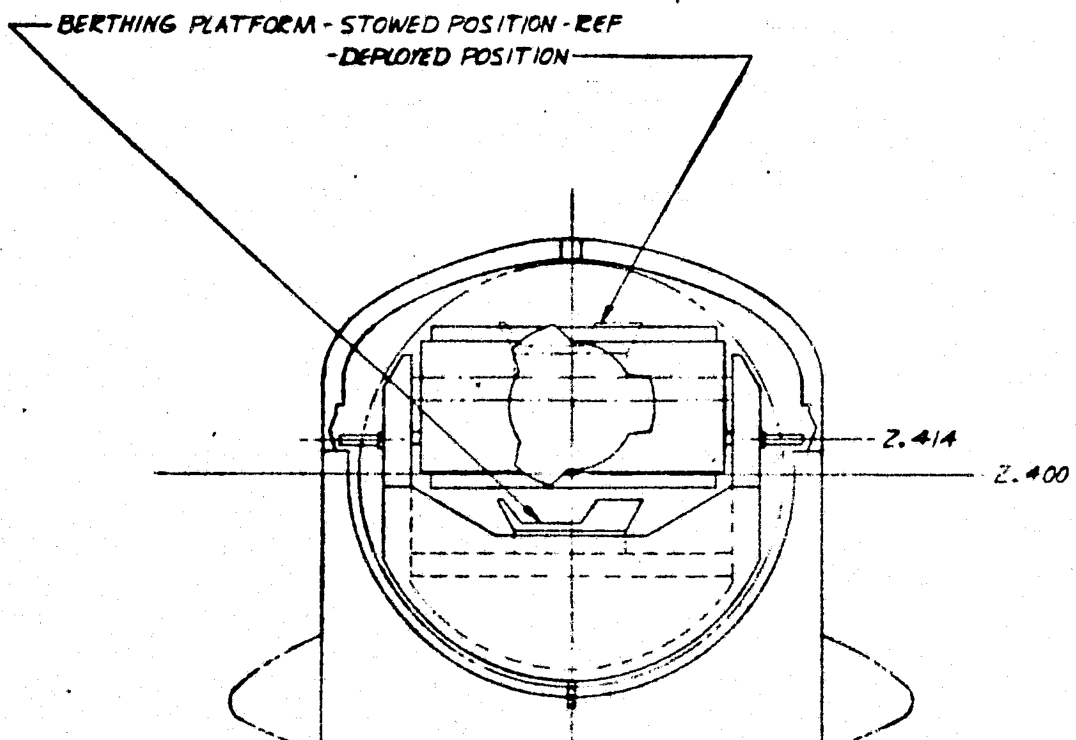
2 FOLDOUT FRAME

SECTION C-C



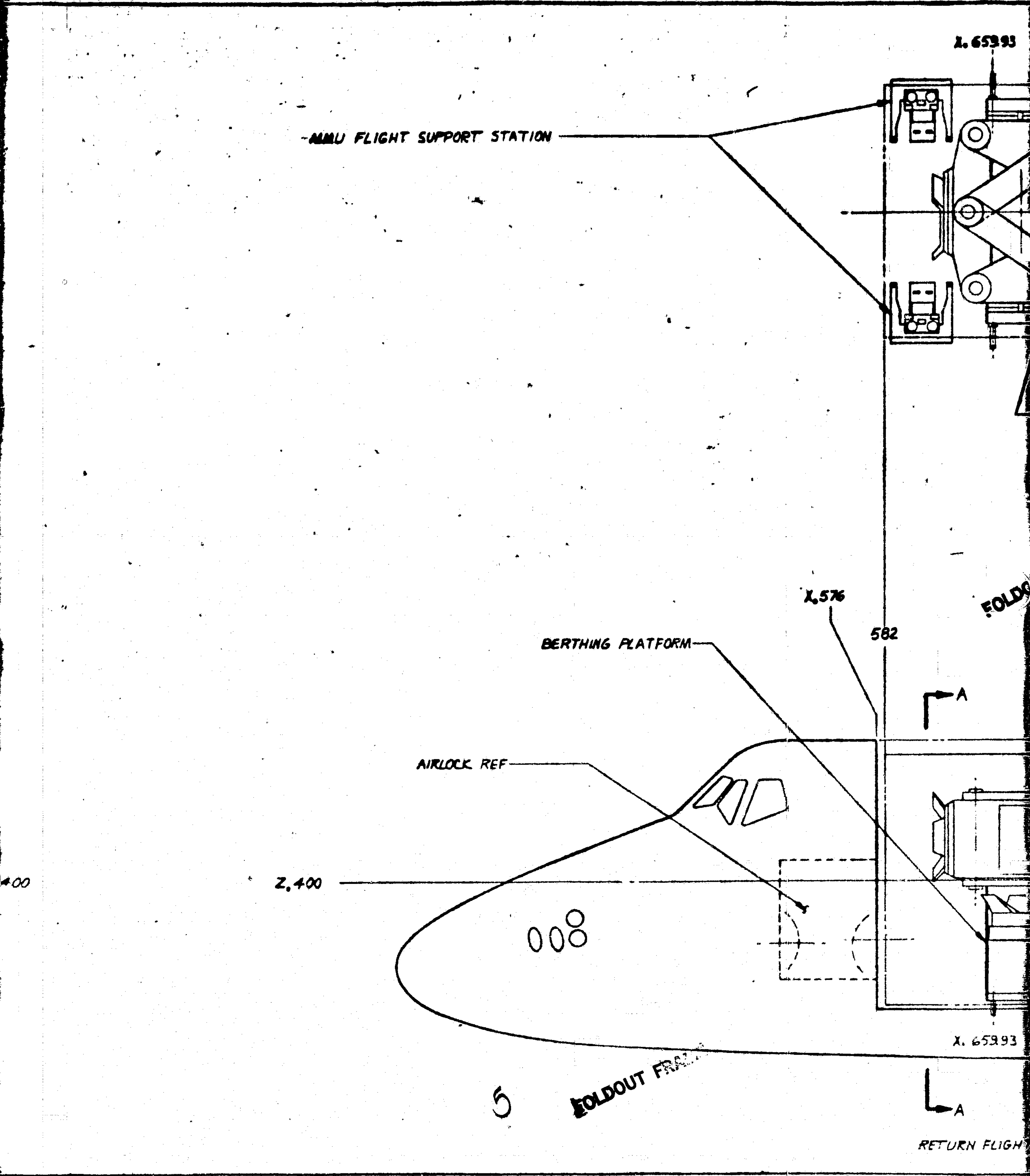
8 FOLDOUT FRAME

SECTION B-B

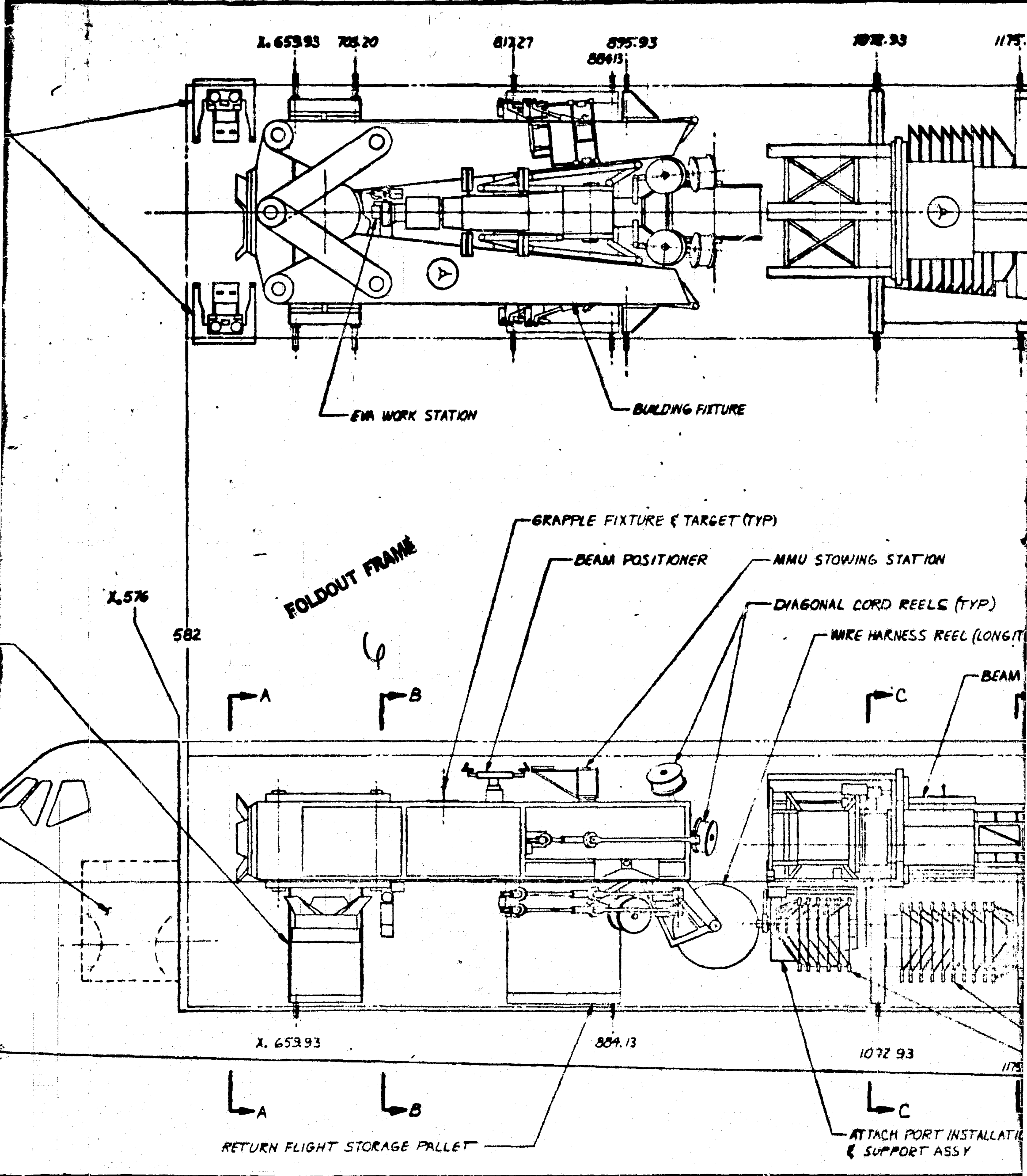


SECTION A-A

4 FOLDOUT FRAME

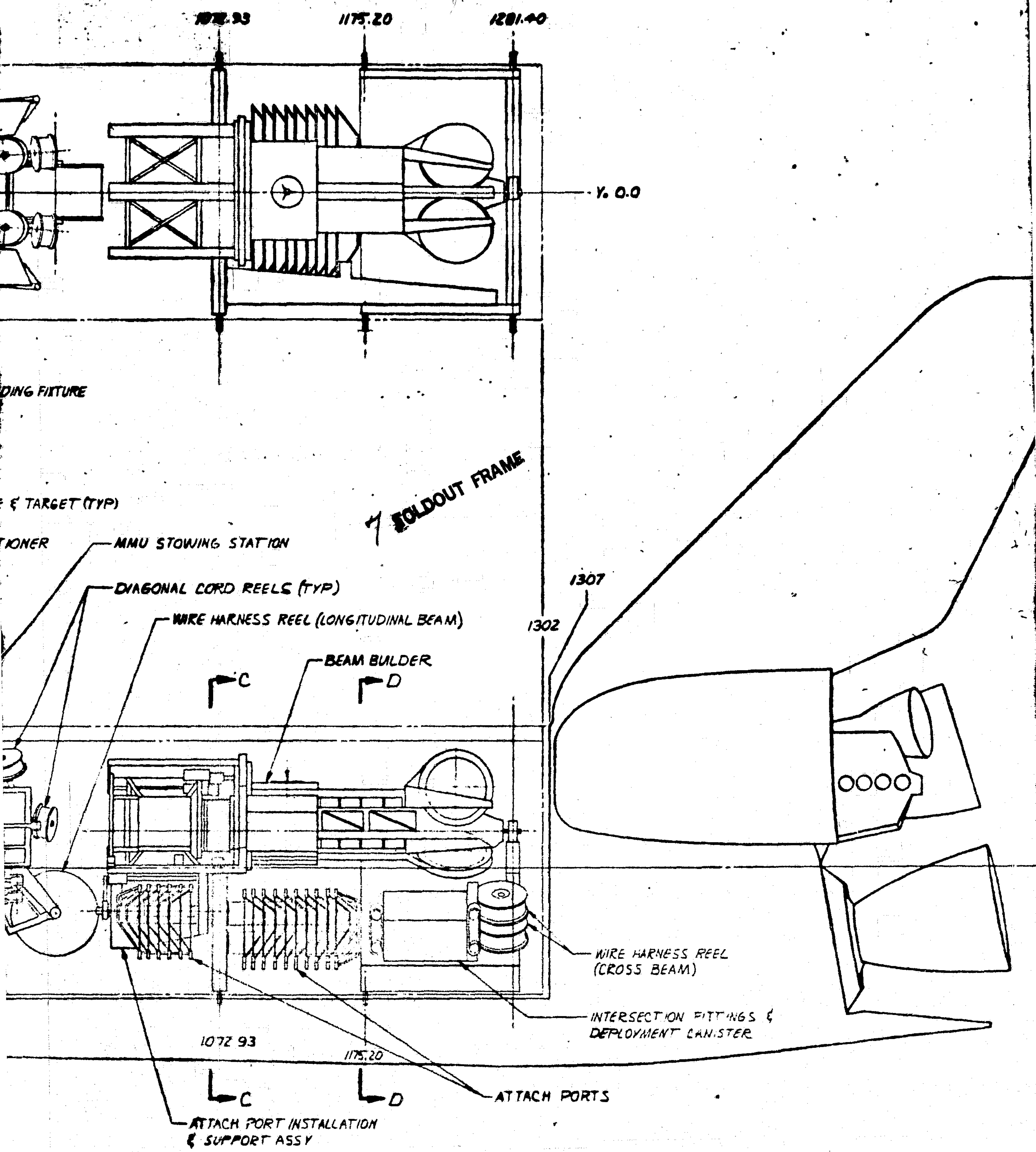

MMU FLIGHT SUPPORT STATION
X, 653.93
X,576
582
BERTHING PLATFORM
A
AIRLOCK REF
Z,400
008
X, 653.93
A

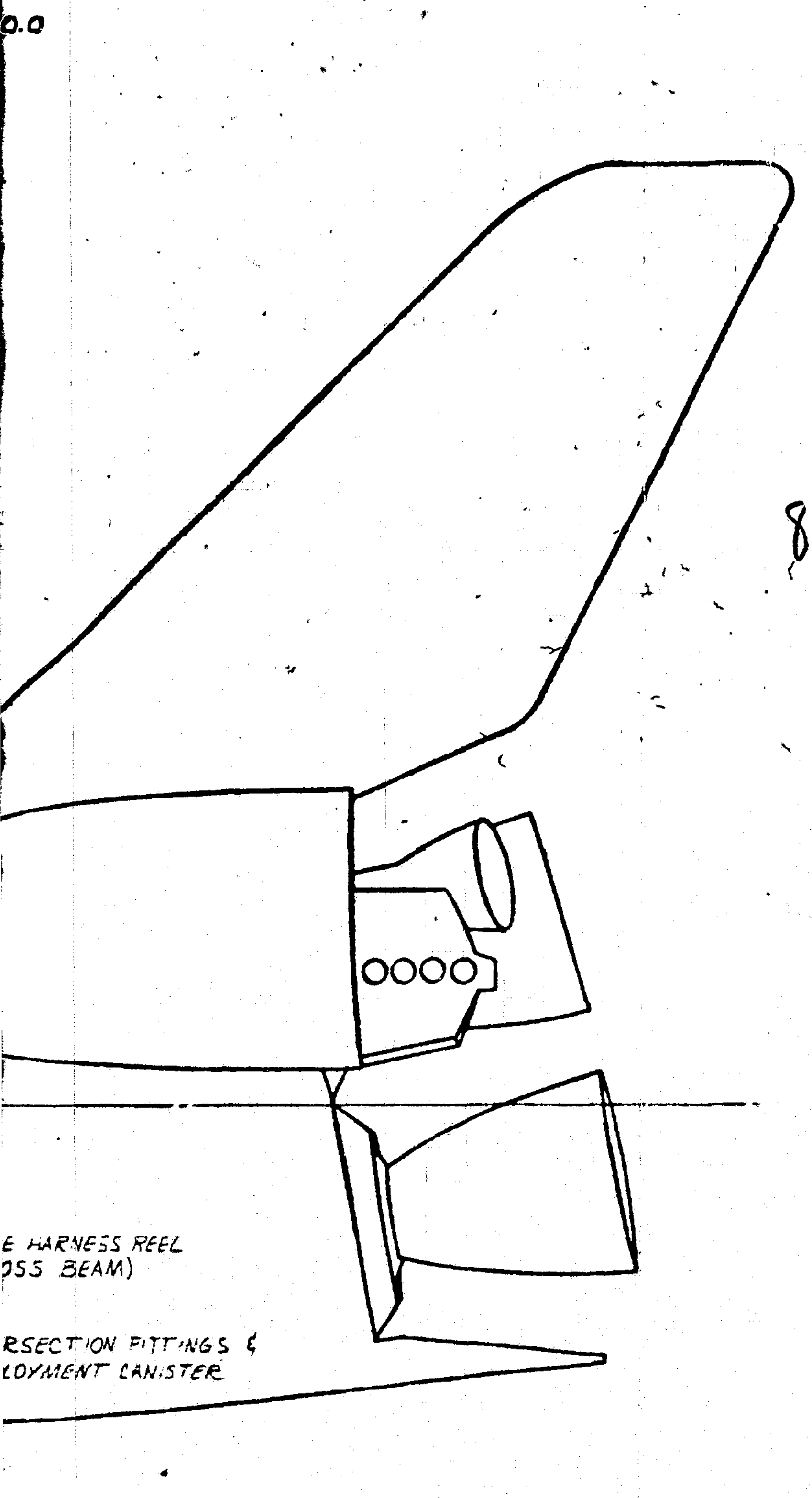
5



X. 653.93
705.20
813.27
895.93
884.13
1072.93
EVA WORK STATION
BUILDING FIXTURE
GRAPPLE FIXTURE & TARGET (TYP)
BEAM POSITIONER
MMU STOWING STATION
DIAGONAL CORD REELS (TYP)
FOLDOUT FRAME
X.576
582
A
B
C
X. 653.93
884.13
1072.93
RETURN FLIGHT STORAGE PALLET
ATTACH PORT INSTALLATI
& SUPPORT ASSY

FOLDOUT FRAME 7





CARGO MANIFEST

1. BUILDING FIXTURE
2. BEAM BUILDER
3. MMU FLIGHT SUPPORT STATION
4. EVA WORK STATION
5. BEAM POSITIONER
6. ATTACH PORTS (28)
7. WIRE HARNESS REEL (LONGITUD
8. WIRE HARNESS REEL (CROSS BE
9. ATTACH PORT INSTALLATION &
10. BERTHING PLATFORM
11. INTERSECTION FITTINGS & DEPL
12. DIAGONAL CORD REELS
13. MMU STOWING STATION

ANIFEST

E

PPORT STATION (2)

TION

ER

(28)

EEL (LONGITUDINAL BEAM)

EEL (CROSS BEAM)

NSTALLATION & SUPPORT ASSY

TFORM

ITTINGS & DEPLOYMENT CANISTER

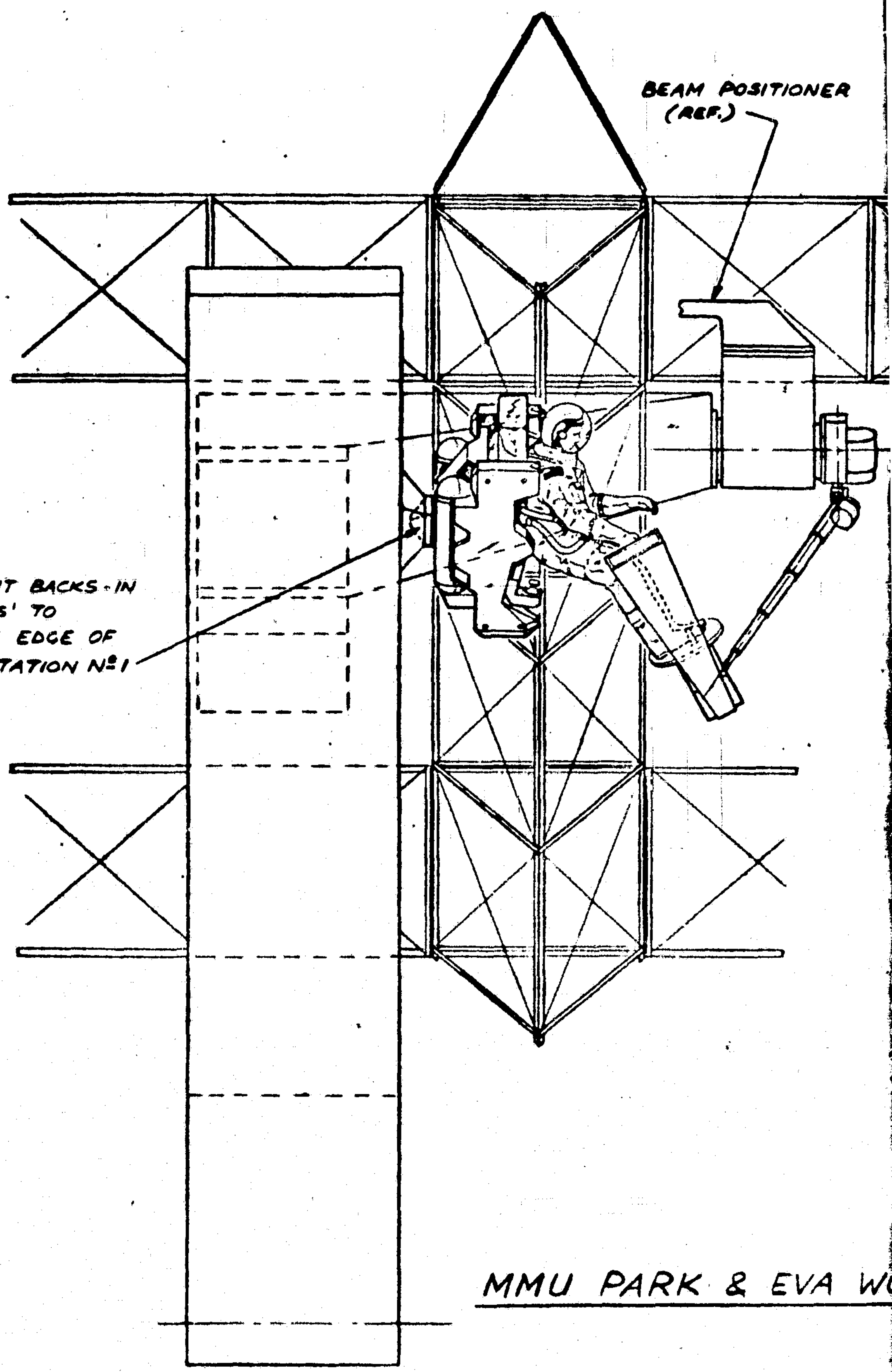
D REELS

STATION

9 FOLDOUT FRAME

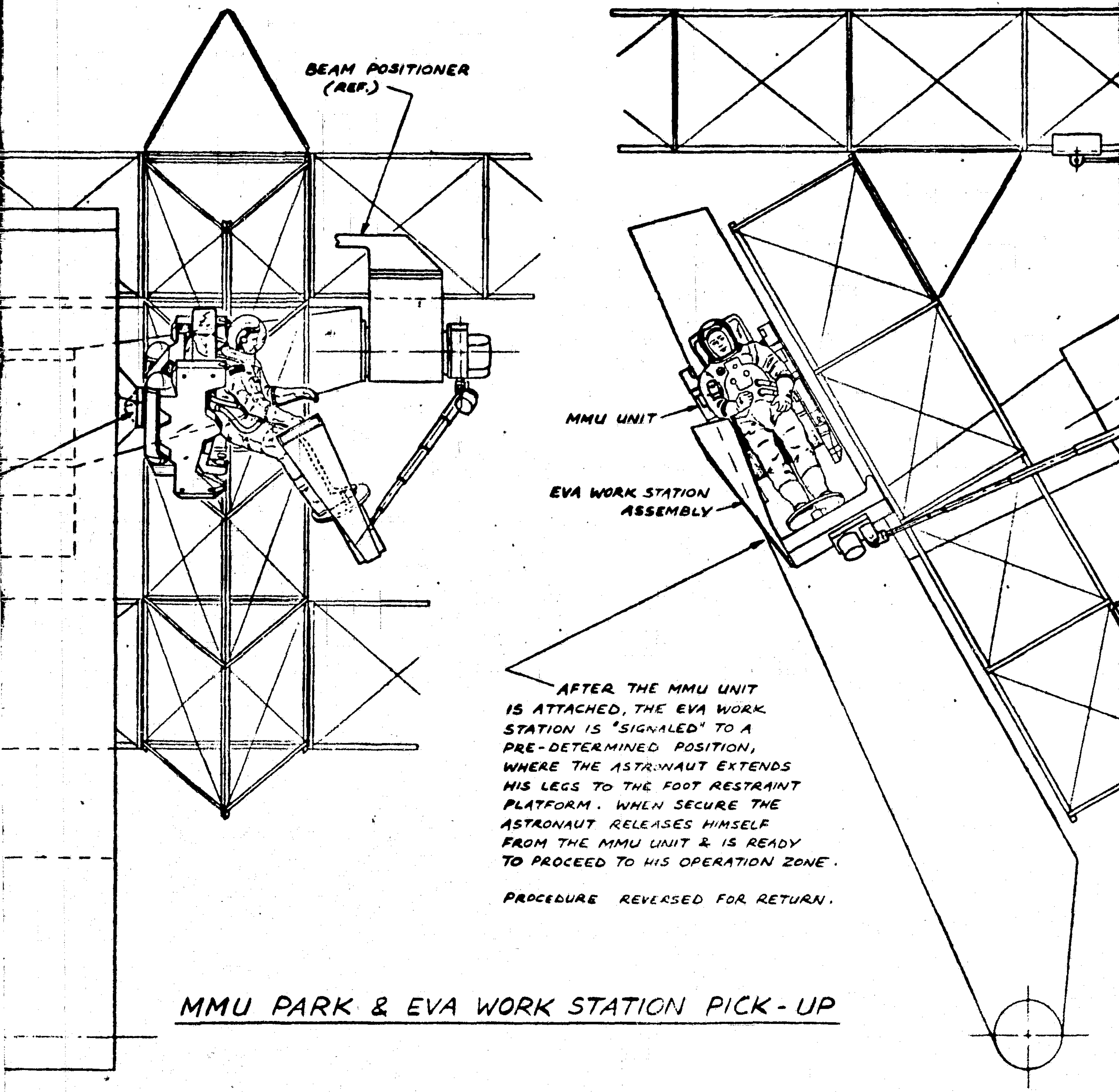
A-19,
A-20

1/40	BY S.A. MILCH DATE	Rockwell International	REVISED & REDRAWN
SHUTTLE BAY PACKAGING - INITIAL FLIGHT			42662-53 REV. "A"



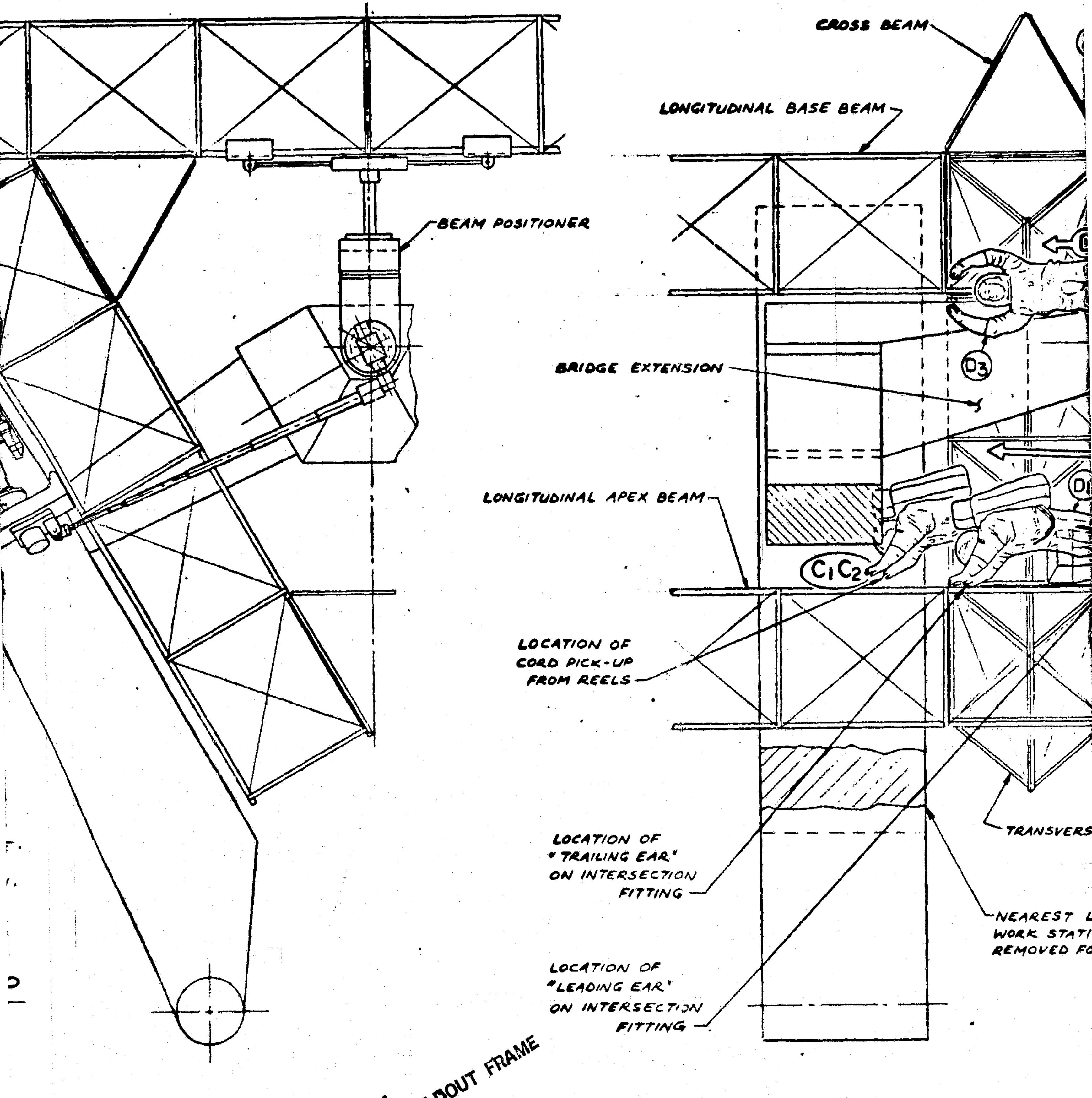
MMU PARK & EVA W

FOLDOUT FRAME

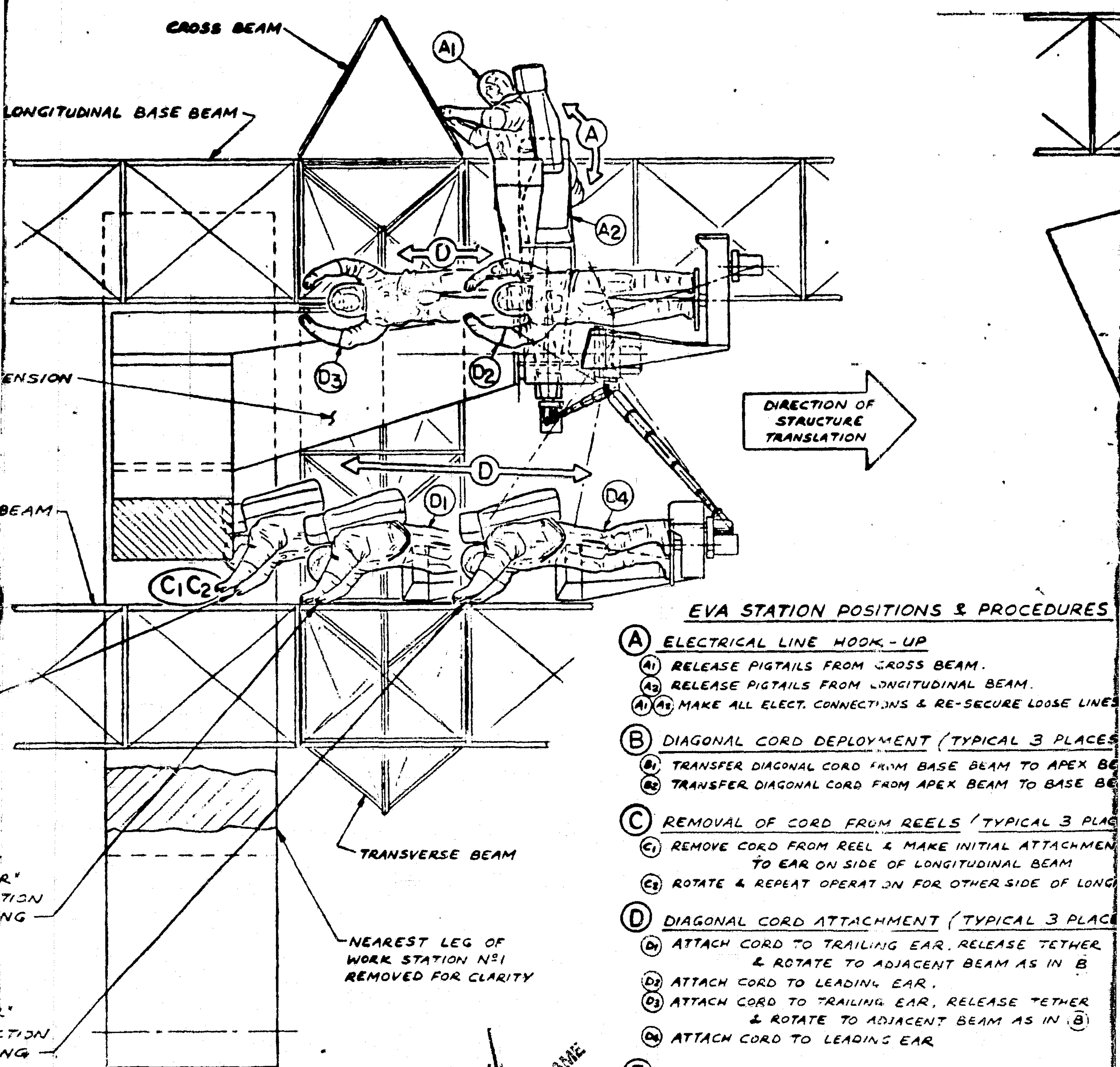


MMU PARK & EVA WORK STATION PICK-UP

2 FOLDOUT FRAME



3 FOLDOUT FRAME



EVA STATION POSITIONS & PROCEDURES

(A) ELECTRICAL LINE HOOK-UP

- (A1) RELEASE PIGTAILS FROM CROSS BEAM.
- (A2) RELEASE PIGTAILS FROM LONGITUDINAL BEAM.
- (A1)(A2) MAKE ALL ELECT. CONNECTIONS & RE-SECURE LOOSE LINES

(B) DIAGONAL CORD DEPLOYMENT (TYPICAL 3 PLACES

- (B1) TRANSFER DIAGONAL CORD FROM BASE BEAM TO APEX BE
- (B2) TRANSFER DIAGONAL CORD FROM APEX BEAM TO BASE BE

(C) REMOVAL OF CORD FROM REELS (TYPICAL 3 PLAC

- (C1) REMOVE CORD FROM REEL & MAKE INITIAL ATTACHMEN TO EAR ON SIDE OF LONGITUDINAL BEAM
- (C2) ROTATE & REPEAT OPERATION FOR OTHER SIDE OF LONG

(D) DIAGONAL CORD ATTACHMENT (TYPICAL 3 PLAC

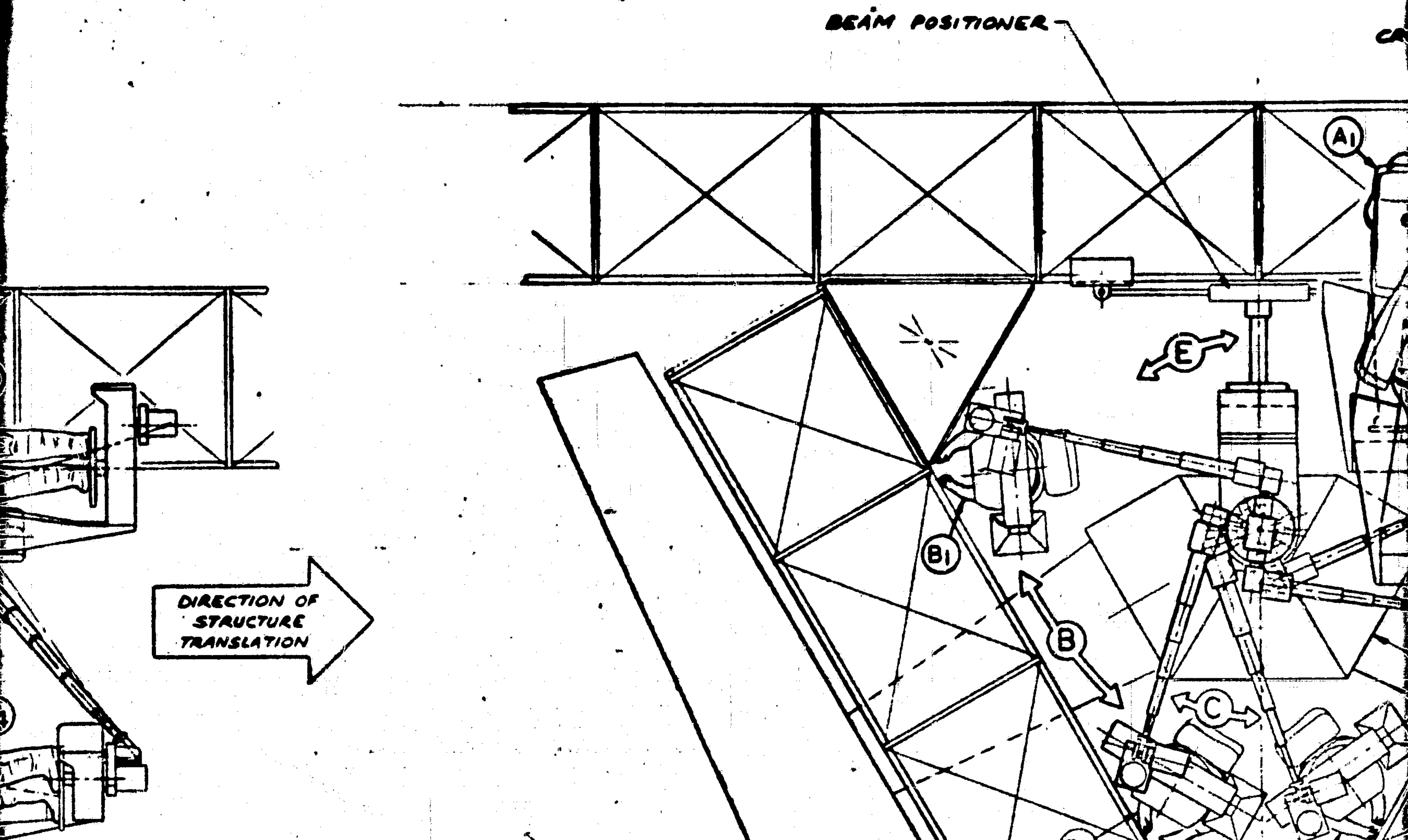
- (D1) ATTACH CORD TO TRAILING EAR. RELEASE TETHER & ROTATE TO ADJACENT BEAM AS IN (B)
- (D2) ATTACH CORD TO LEADING EAR.
- (D3) ATTACH CORD TO TRAILING EAR, RELEASE TETHER & ROTATE TO ADJACENT BEAM AS IN (B)
- (D4) ATTACH CORD TO LEADING EAR

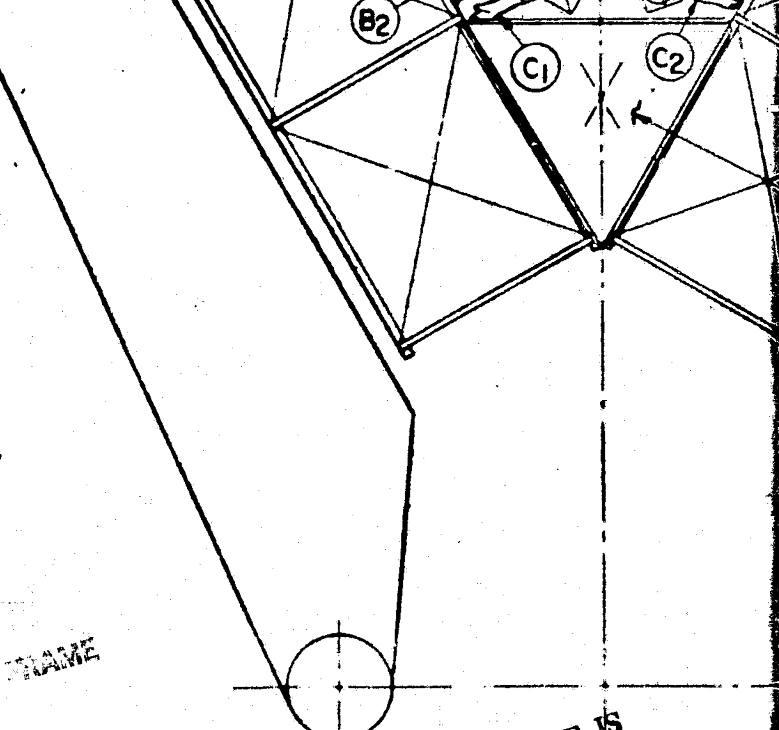
(E) BEAM POSITIONER

- SHOWN IN POSITION FOR ASSEMBLING CROSS BEAM
- AFTER BEAM ASSEMBLY OPERATIONS ARE COMPLETE OF PLANE IN WHICH EVA FUNCTIONS ARE

4

FOLDOUT FRAME





EVA STATION POSITIONS & PROCEDURES

(A) ELECTRICAL LINE HOOK-UP

- (A1) RELEASE PIGTAILS FROM CROSS BEAM.
- (A2) RELEASE PIGTAILS FROM LONGITUDINAL BEAM.
- (A1)(A2) MAKE ALL ELECT. CONNECTIONS & RE-SECURE LOOSE LINES TO BEAMS.

(B) DIAGONAL CORD DEPLOYMENT (TYPICAL 3 PLACES)

- (B1) TRANSFER DIAGONAL CORD FROM BASE BEAM TO APEX BEAM.
- (B2) TRANSFER DIAGONAL CORD FROM APEX BEAM TO BASE BEAM.

(C) REMOVAL OF CORD FROM REELS (TYPICAL 3 PLACES)

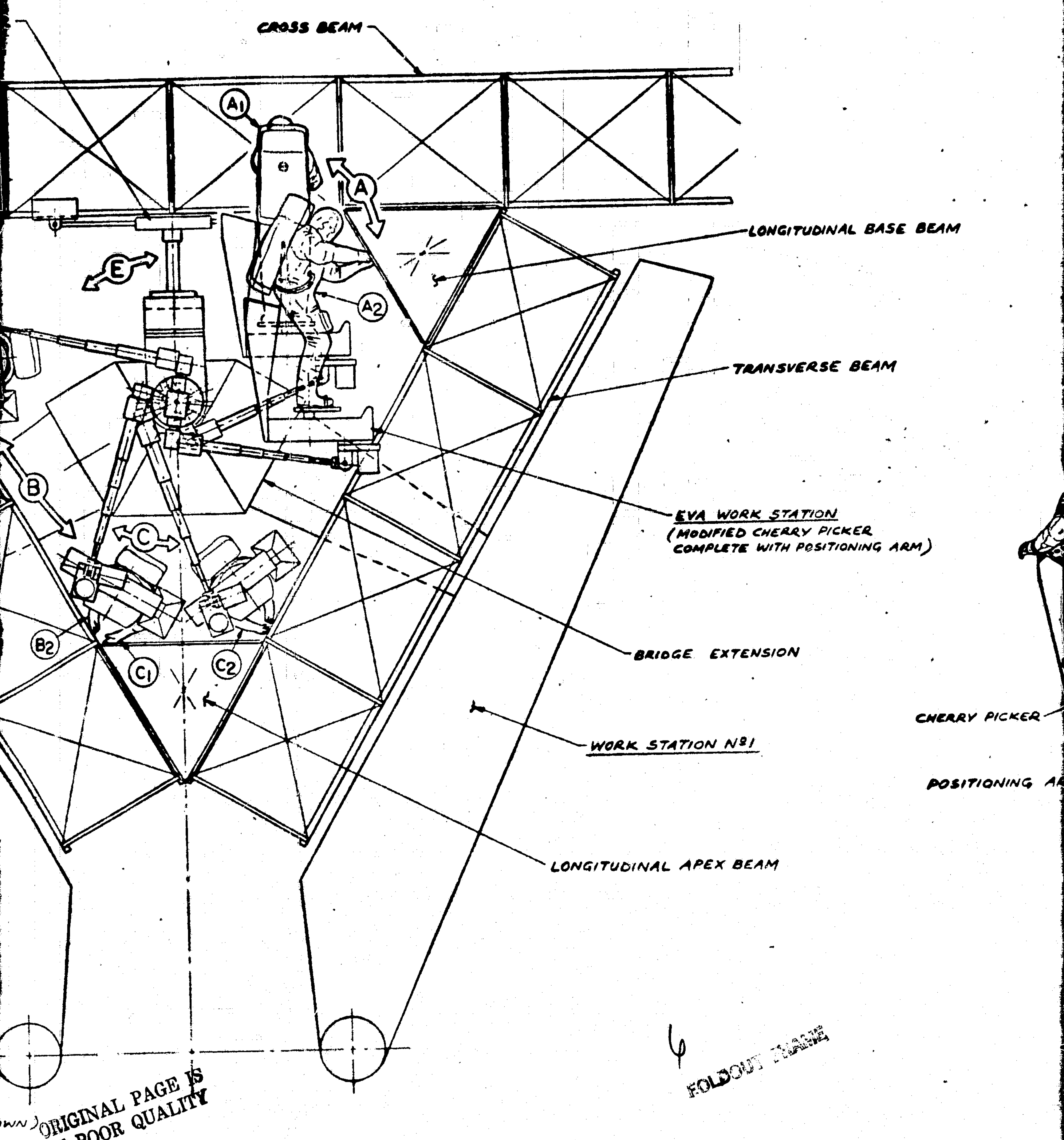
- (C1) REMOVE CORD FROM REEL & MAKE INITIAL ATTACHMENT TO EAR ON SIDE OF LONGITUDINAL BEAM
- (C2) ROTATE & REPEAT OPERATION FOR OTHER SIDE OF LONGITUDINAL BEAM

(D) DIAGONAL CORD ATTACHMENT (TYPICAL 3 PLACES)

- (D1) ATTACH CORD TO TRAILING EAR, RELEASE TETHER & ROTATE TO ADJACENT BEAM AS IN (B)
- (D2) ATTACH CORD TO LEADING EAR.
- (D3) ATTACH CORD TO TRAILING EAR, RELEASE TETHER & ROTATE TO ADJACENT BEAM AS IN (B)
- (D4) ATTACH CORD TO LEADING EAR

(E) BEAM POSITIONER

- SHOWN IN POSITION FOR ASSEMBLING CROSS BEAM - EVA WILL ASSIST (POSITION NOT SHOWN)
- AFTER BEAM ASSEMBLY OPERATIONS ARE COMPLETE, BEAM IS ROTATED CLEAR OF PLANE IN WHICH EVA FUNCTIONS ARE BEING PERFORMED.



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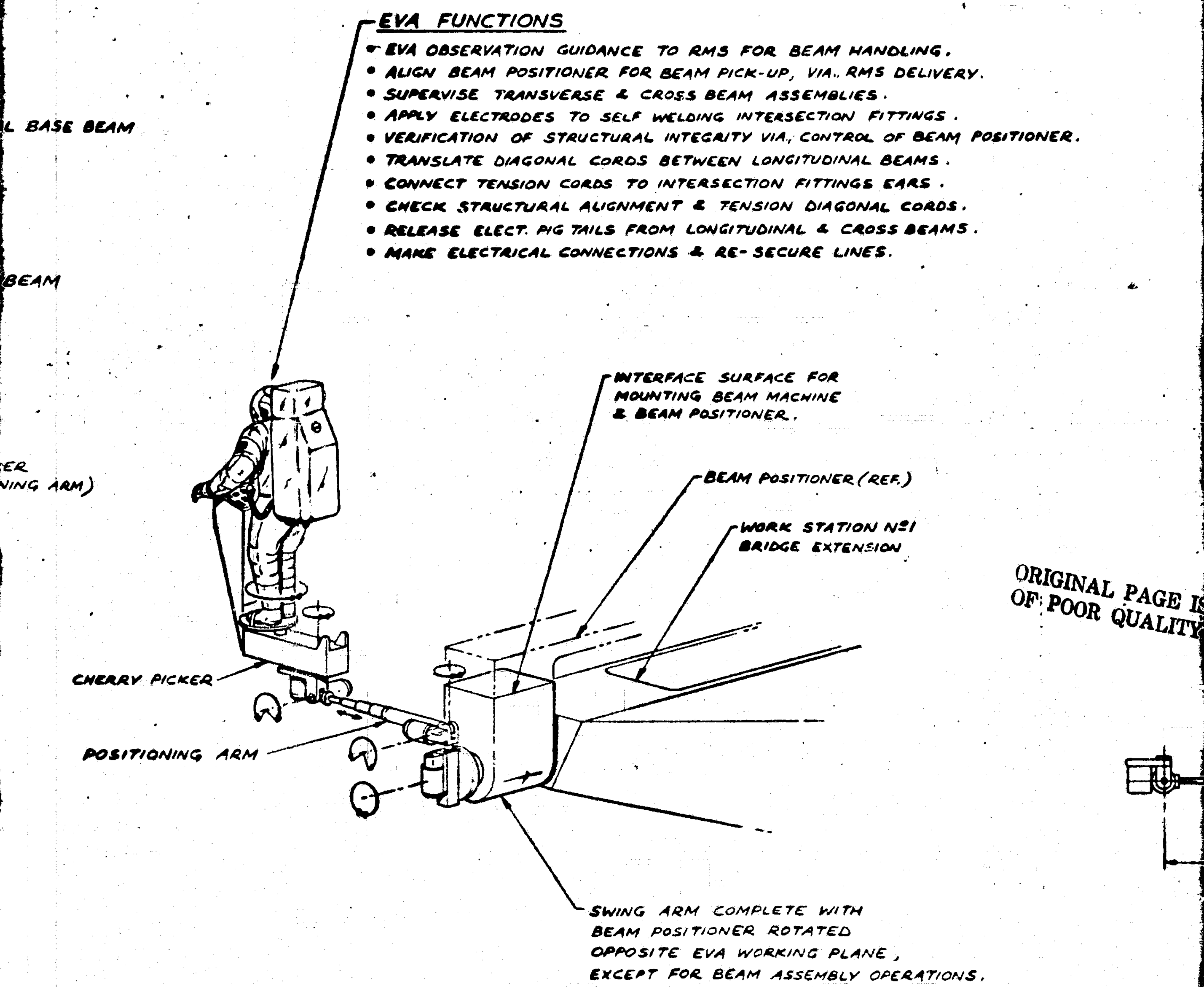
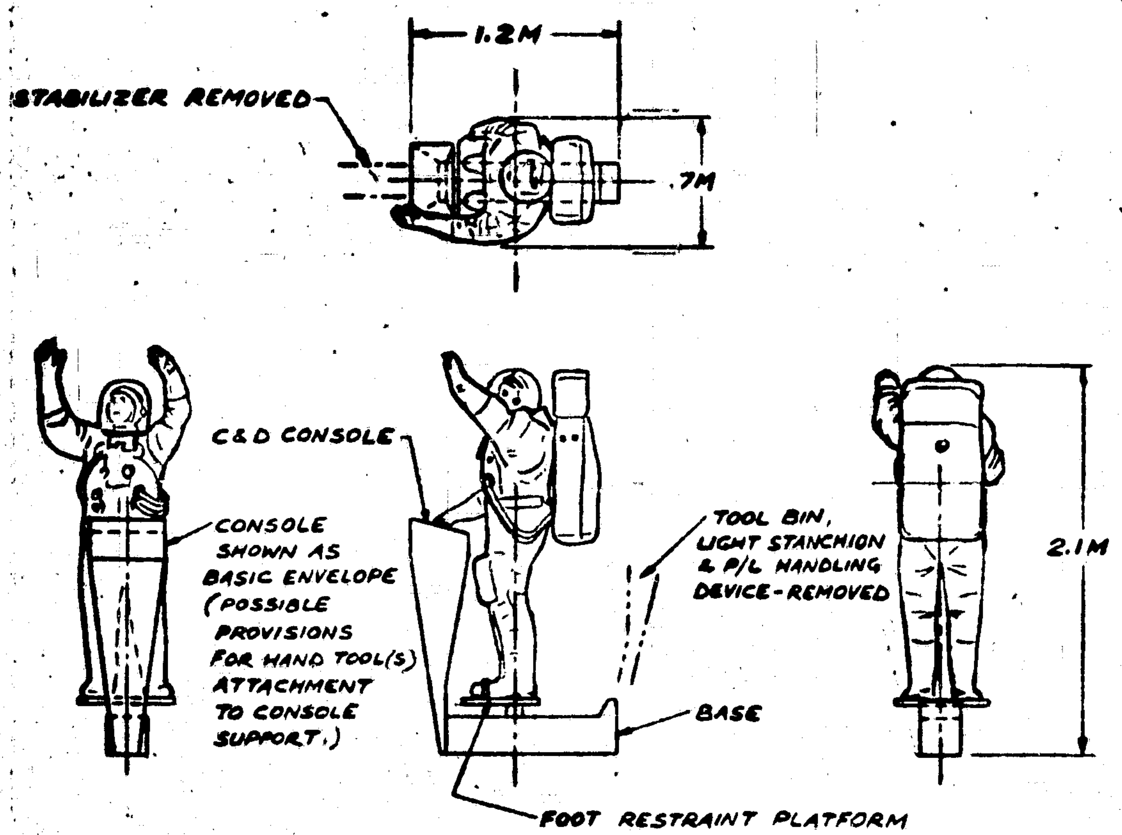
OF POOR QUALITY

FOLDOUT FRAME



EVA WORK STATION



BASIC CHERRY PICKER CONFIGURATION COMPLETE WITH ASTRONAUT, AS ADAPTED FOR USE WITH WORK STATION Nº1

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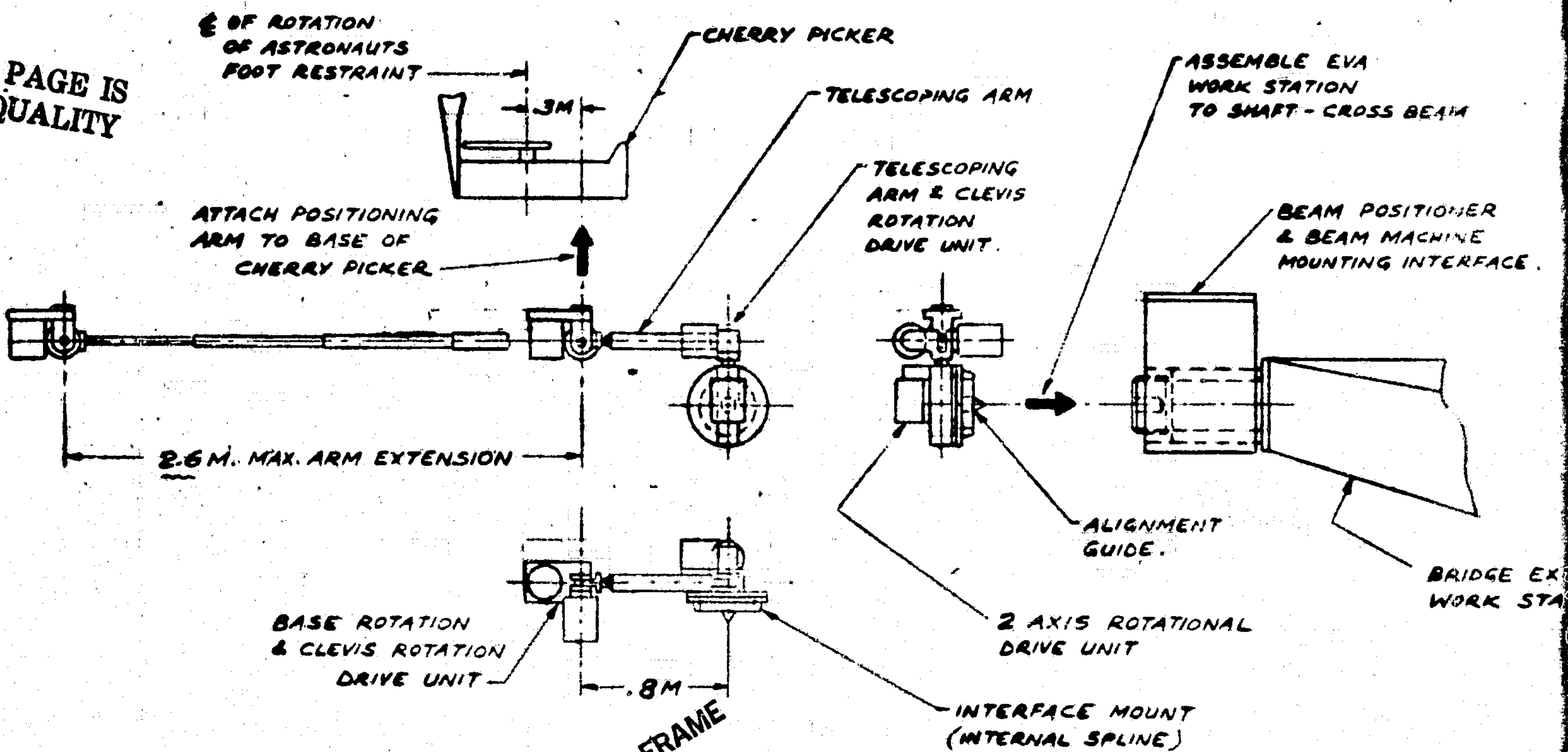
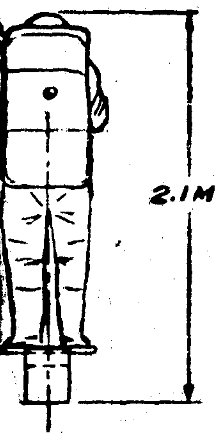


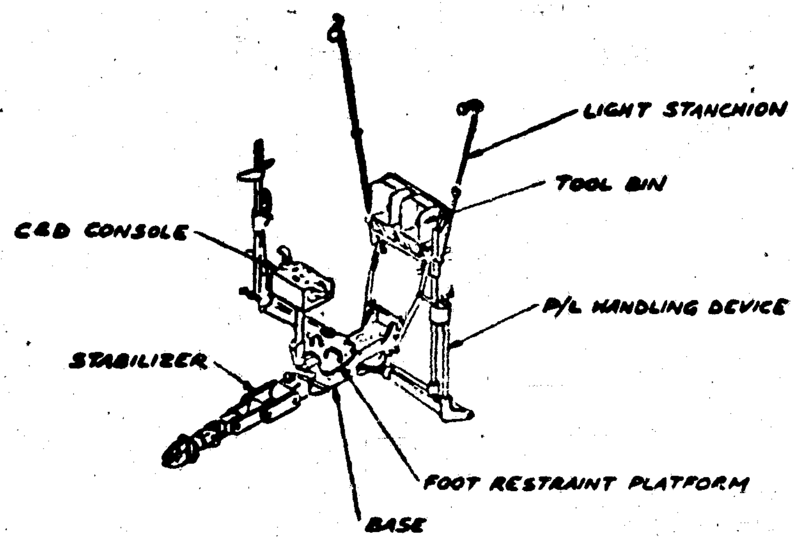
8 FOLDOUT FRAME

POSITIONING ARM

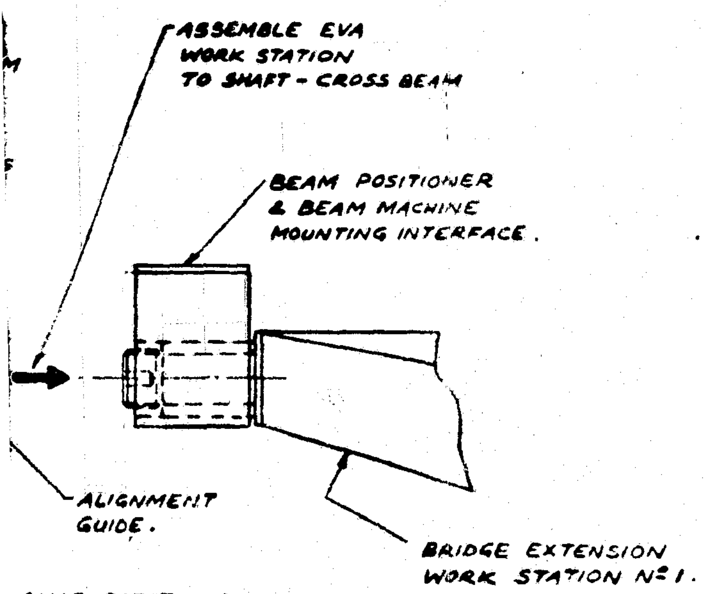


M

ETE WITH
ATION Nº1



OPEN CHERRY PICKER DEVELOPMENT TEST ARTICLE
"AS IS" CONFIGURATION



AXIS ROTATIONAL
IVE UNIT

FACE MOUNT
NAL SPLINE)

M

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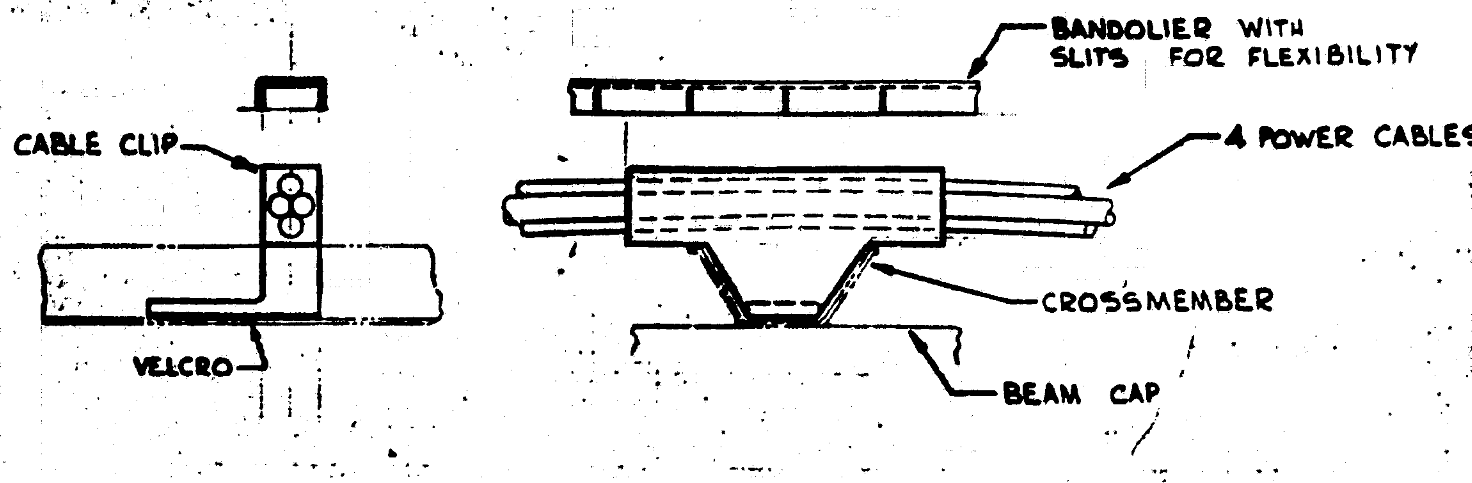
9 FOLDOUT FRAME

A-21,
A-22

SCALE 1/20	DR BUCK / DATE 10/21/79 / MODEL ECSA	ROCKWELL INTERNATIONAL CORPORATION SPACE DIVISION 12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA	
EVA WORK STATION			42662-55

24 23 22

D



DETAIL OF CABLE CLIP

SCALE: FULL SIZE

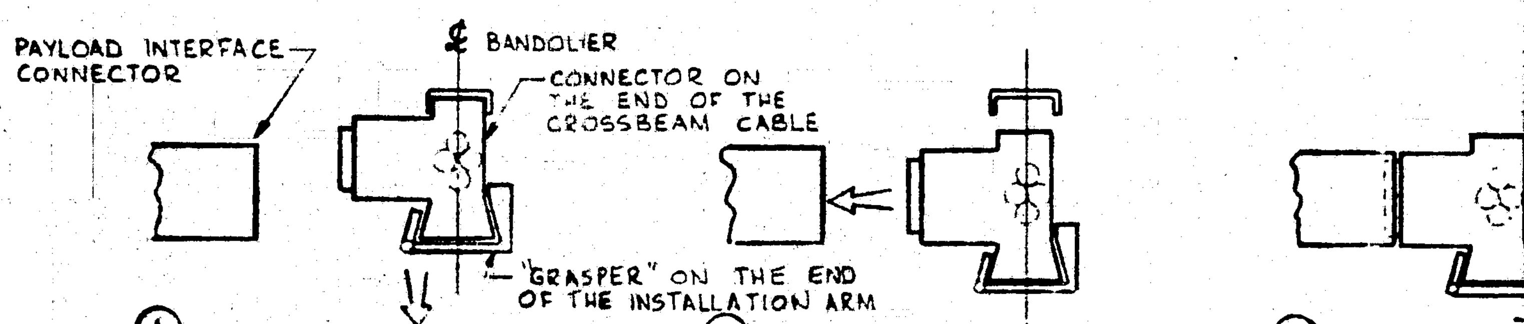
C

- RELATIVE EXPANSION CONTRACTION BETWEEN ELECTRIC CABLE & STRUCTURE OVER ±100°F.
- DISTANCE BETWEEN CLIPS = 1.434 M.
- STRUCTURE ASSUMED TO HAVE ZERO EXPANSION.
- CABLE (COPPER) HAS ±1.32MM EXPANSION BETWEEN CLIPS.
- PROVIDE SLACK IN CABLE TO ACCOMODATE ±1.32 MM.
- DESIGN THE CABLE CLIP AS SHOWN TO INDUCE A CURVE IN THE CABLE TO PROVIDE THE NECESSARY SLACK.

FOLDOUT FRAME

B

SEQUENCE OF EVENTS FOR ... TO PAYLOAD ...



A

(1)

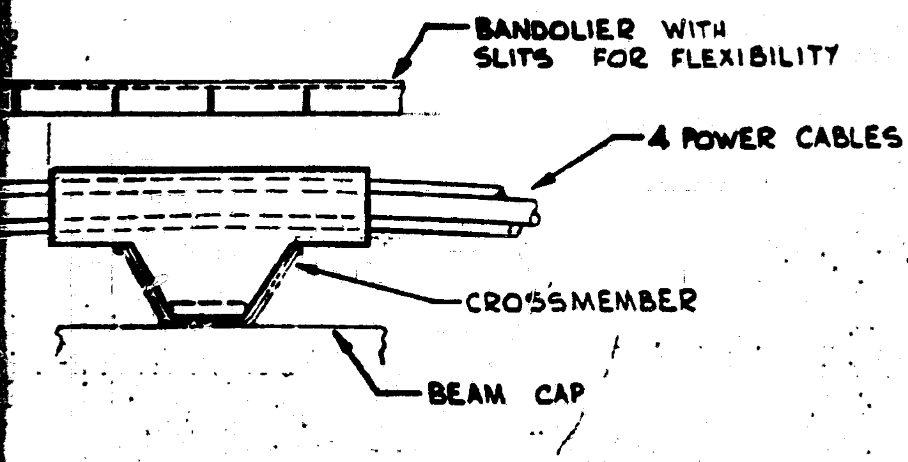
- THE BEAM IS HALTED
- THE XBEAM CABLE CONNECTOR IS IN THE BANDOLIER & OPPOSITE THE PAYLOAD INTERFACE CONNECTOR
- THE GRASPER HAS GRASPED THE X BEAM CABLE CONNECTOR

(2)

- THE GRASPER STRIPS THE XBEAM CABLE CONNECTOR FROM THE BANDOLIER

(3)

- THE GRASPER ... THE X BEAM ... CONNECTOR TO PAYLOAD INTER... CONNECTOR



ABLE CLIP
FULL SIZE

BETWEEN ELECTRIC CABLE

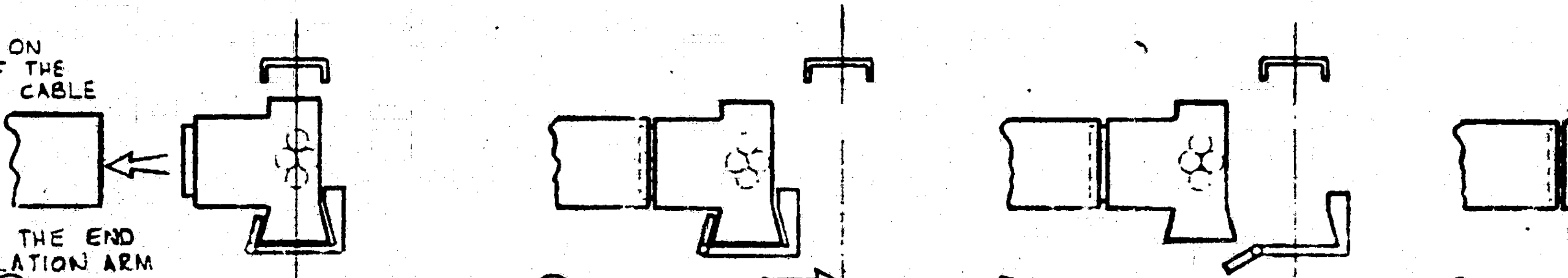
-434 M.
IE ZERO EXPANSION.
M EXPANSION BETWEEN CLIPS.
ACCOMODATE ±1.32 MM.
SHOWN TO INDUCE A CURVE
THE NECESSARY SLACK.

2

FOLDOUT FRAME

SEQUENCE OF EVENTS FOR MATING CROSSBEAM CABLE CONNECTORS
TO PAYLOAD INTERFACE CONNECTORS

CTOR ON
ND OF THE
BEAM CABLE



R" ON THE END
INSTALLATION ARM

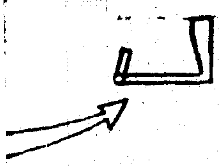
ITE
CTOR
IE

(2)
- THE GRASPER STRIPS THE XBEAM CABLE CONNECTOR FROM THE BANDOLIER

(3)
- THE GRASPER MATES THE X BEAM CABLE CONNECTOR TO THE PAYLOAD INTERFACE CONNECTOR

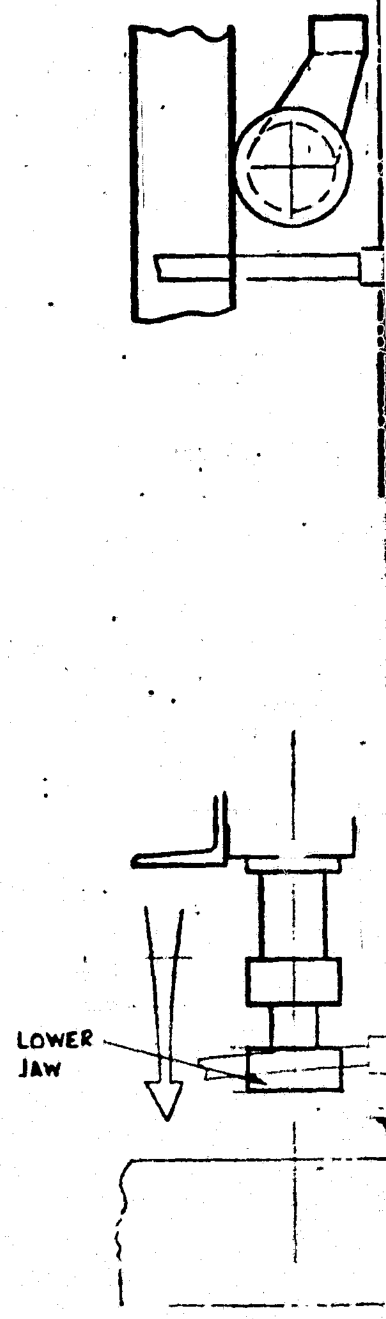
(4)
- THE GATE ON THE GRASPER OPENS.
THE GRASPER RETREATS

(5)
- THE
THE
CABLE



3

FOLDOUT FRAME



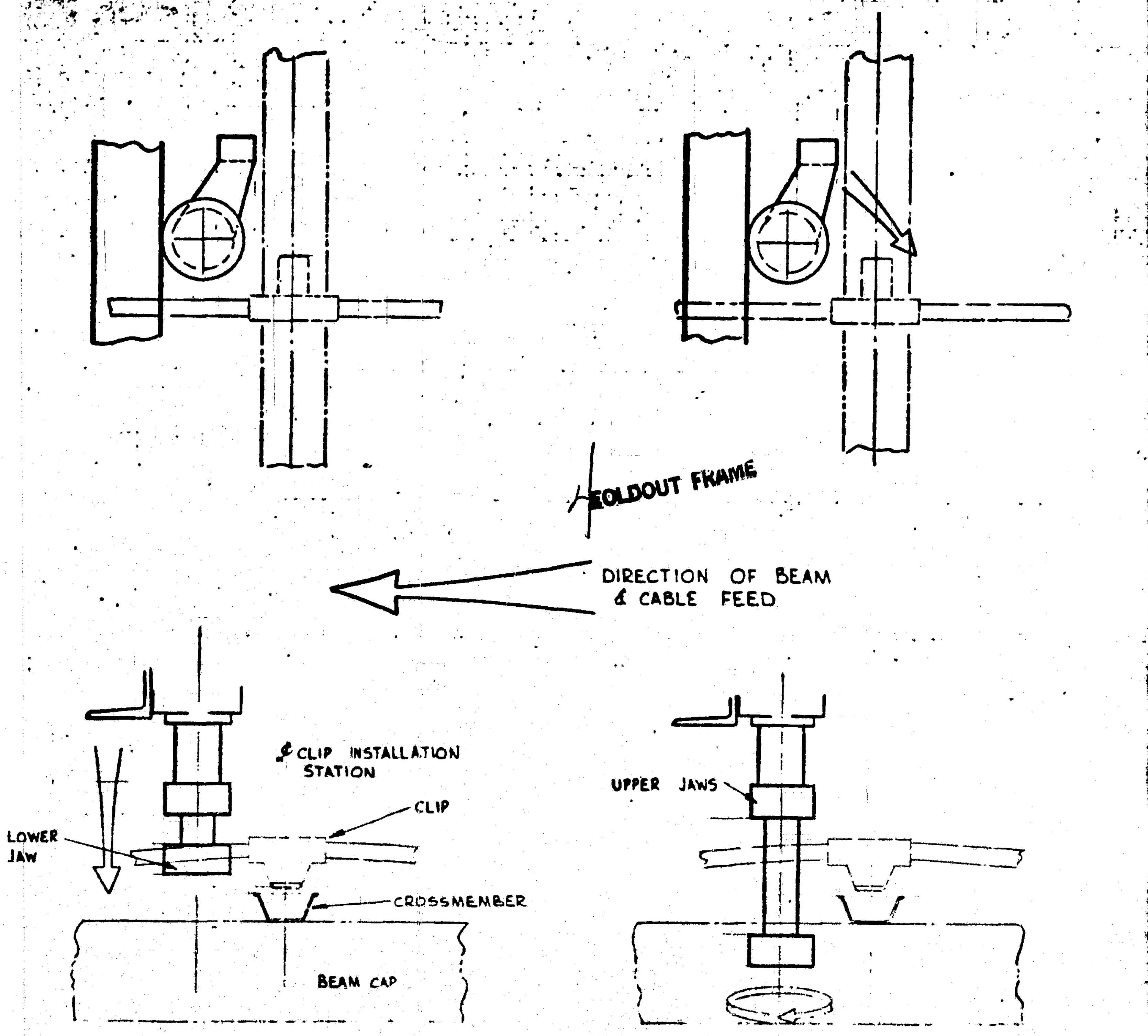
OUT OF
DWING

(1) ● BEAM HA
(STD

● CLIP IS

● REEL
● LOWER

16 15 14

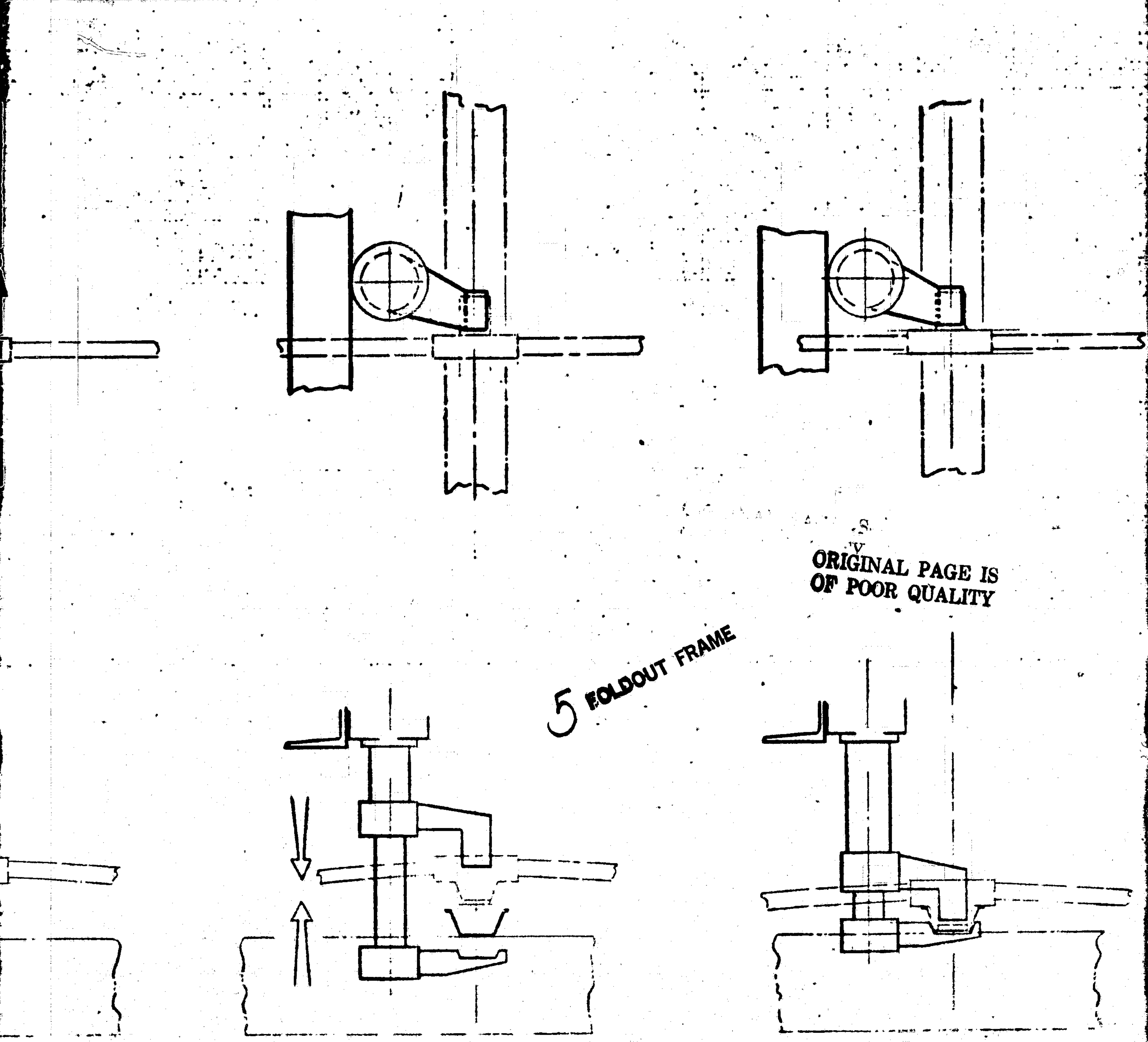


(1)
- BEAM HALTS FOR 40 SECS
  (STD BEAM BUILDER SEQUENCING)
- CLIP IS ALIGNED WITH CROSSMEMBER
- REEL FEED IS HALTED
- LOWER JAW BEGINS TO EXTEND

(2)
- LOWER JAW IS FULLY EXTENDED
- LOWER & UPPER JAWS BEGIN TO ROTATE

SEQUENCE OF EVENTS

SCALE :



S FULLY EXTENDED
PPER JAWS BEGIN

(3) • LOWER & UPPER JAWS ARE FULLY ROTATED
• JAWS BEGIN TO SQUEEZE

(4) • JAWS ARE SQUEEZED &
CLIP IS INSTALLED ON

(5) • REVERSE (1)(2)(3)(4) TO C
THE CYCLE

UENCE OF EVENTS FOR CLIP INSTALLATION

SCALE : 1/2

11 10 9 8

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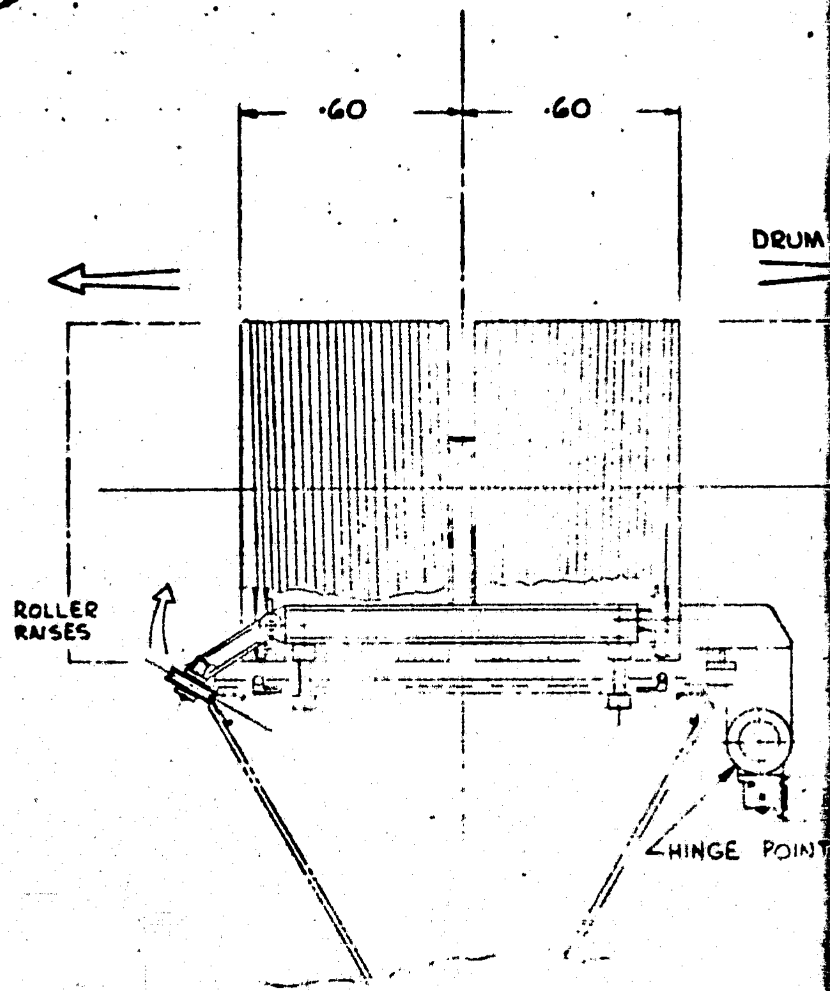
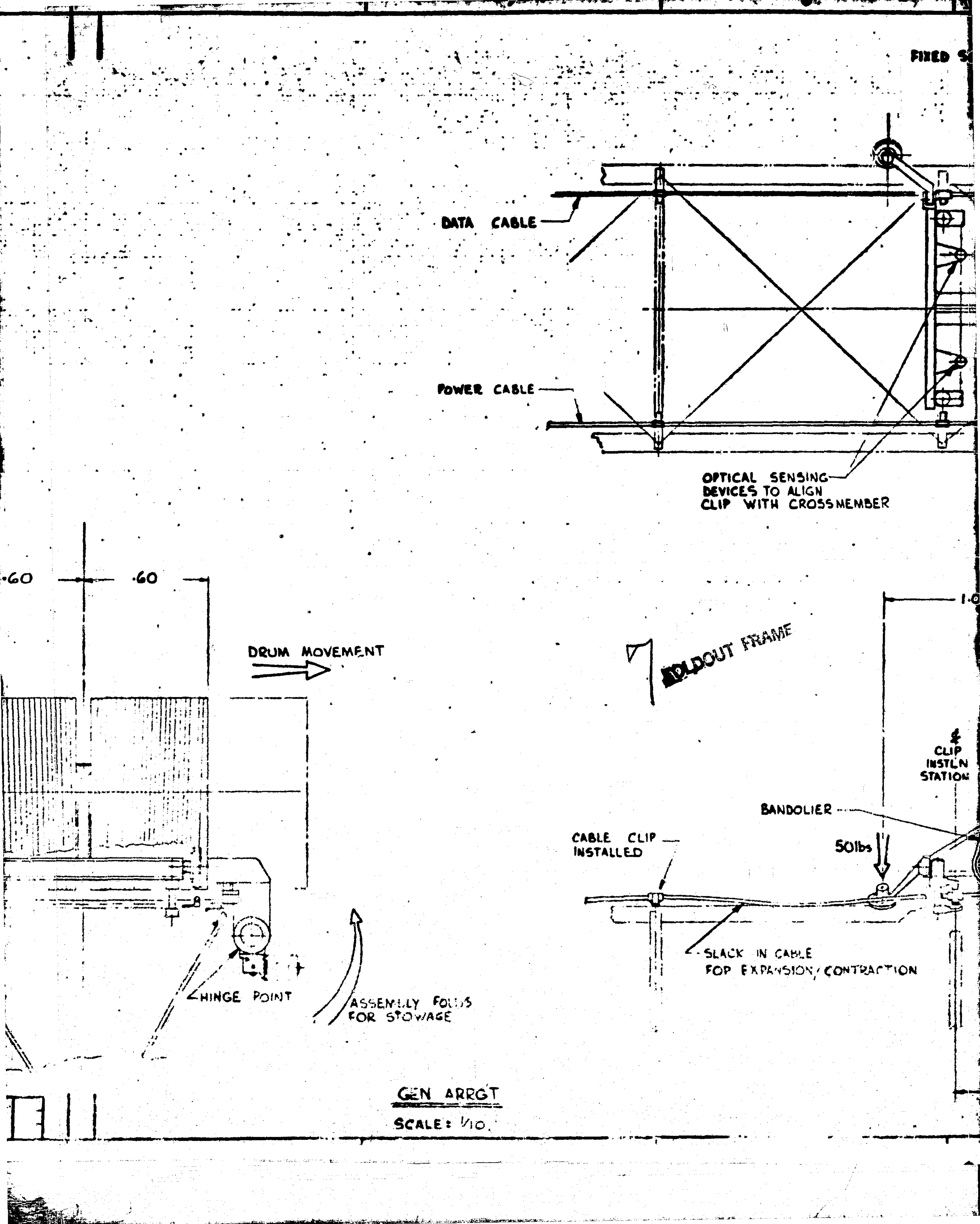
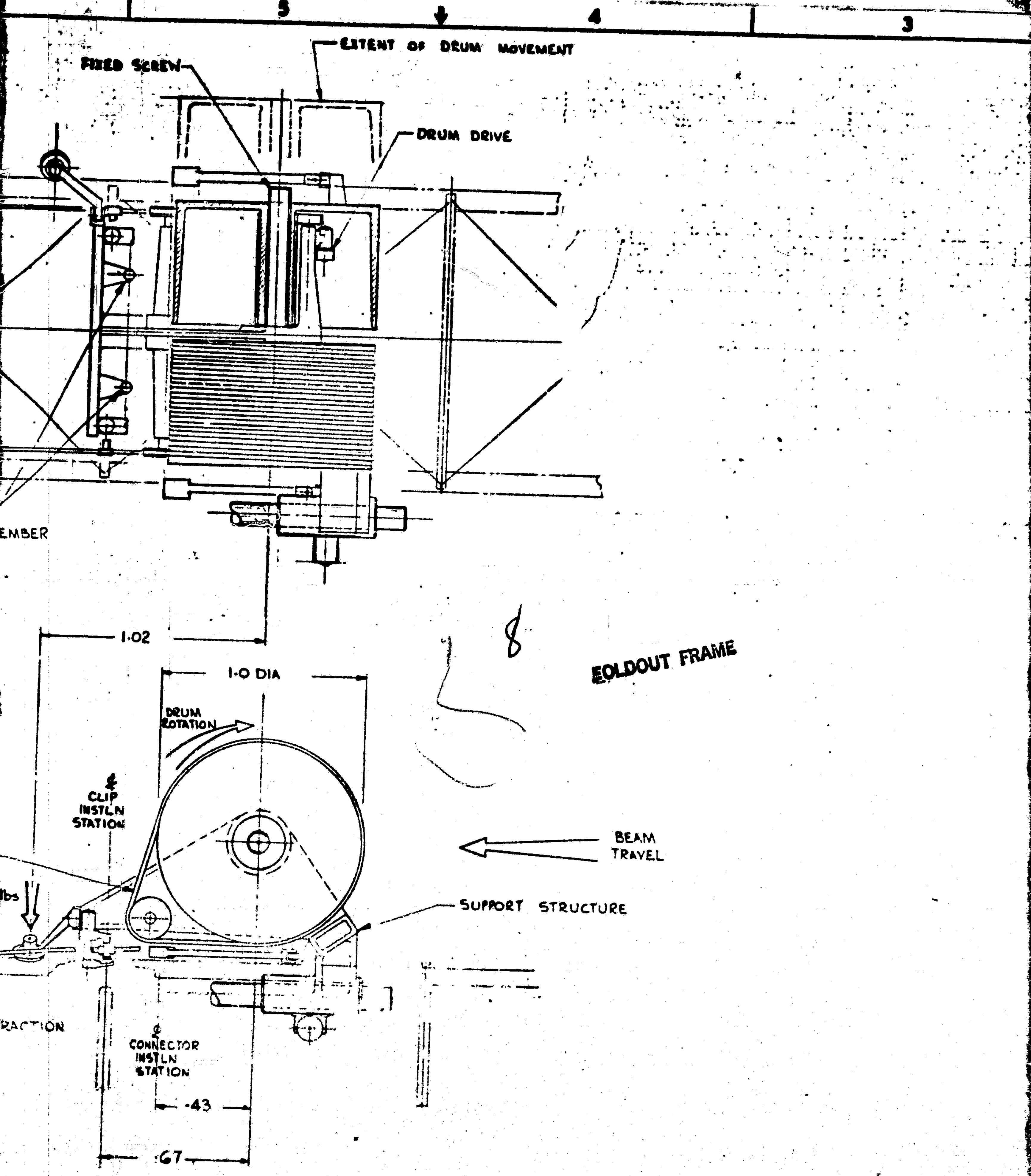


ON CROSSMEMBER

COMPLETE

42662-56


FIXED
DATA CABLE
POWER CABLE
OPTICAL SENSING DEVICES TO ALIGN CLIP WITH CROSSMEMBER
·60
·60
DRUM MOVEMENT
CLIP INSTL'N STATION
BANDOLIER
CABLE CLIP INSTALLED
50lbs
SLACK IN CABLE FOR EXPANSION/CONTRACTION
HINGE POINT
ASSEMBLY FOLDS FOR STOWAGE
GEN ARRGT
SCALE: 1/10.



8

FOLDOUT FRAME

3	2	1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

D

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OF POOR QUALITY

C

9 FOLDOUT FRAME

REFERENCE DWGS
42662-52 No 2 CONSTRUCTION STATION
42662-61 WIRING DWG

B

A A23
A24

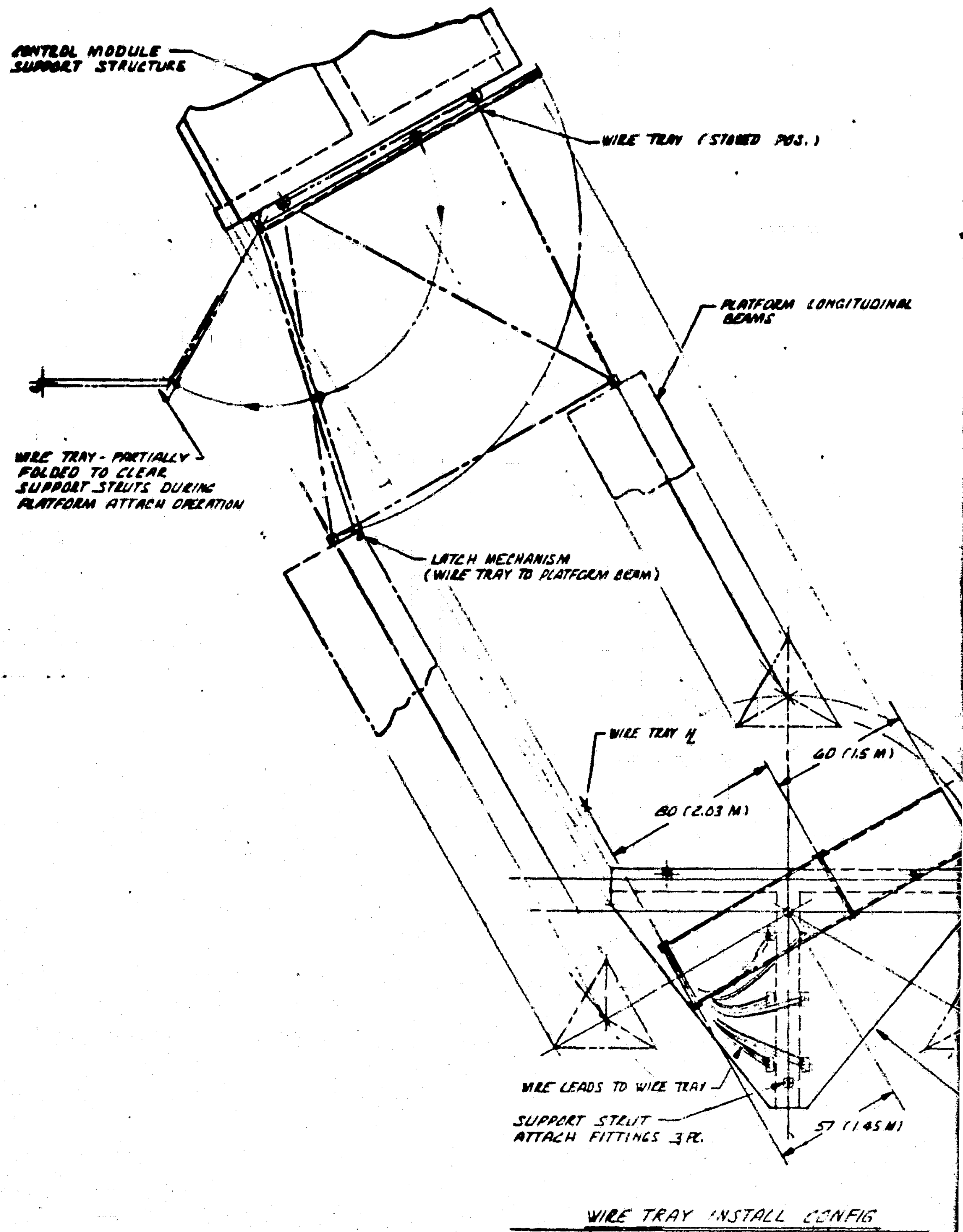
DR BY	R. HART	NOV
CHK BY		
APPROVED BY		

Rockwell International Corporation
Space Division

ELECTRIC CABLE LAYING MACHINE, CROSSBEAM E.T.V.P

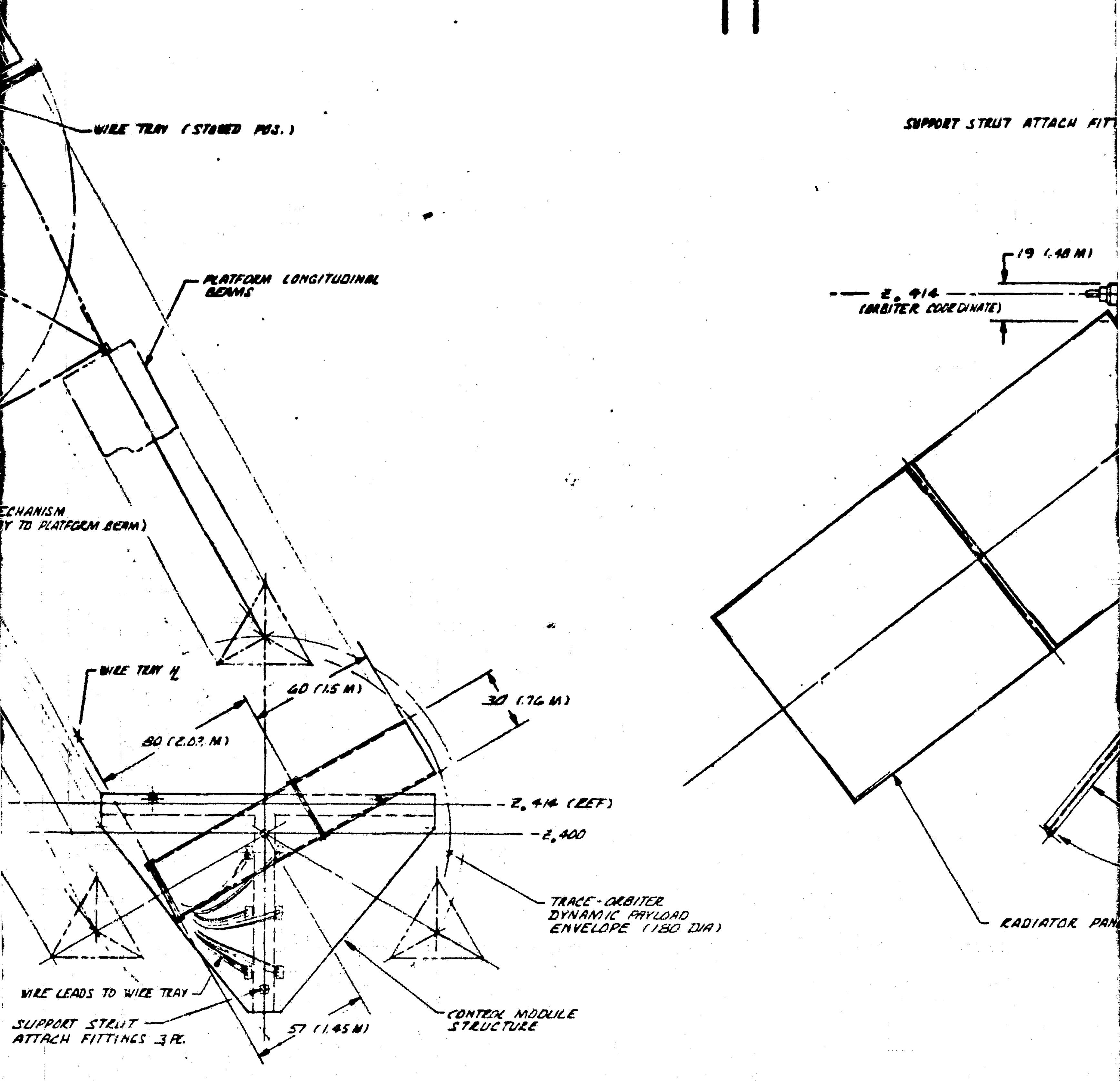
SIZE	CODE IDENT NO	DRAWING NO.
I	03953	42662-56

SCALE NOTED



WIRE TRAY INSTALL CONFIG

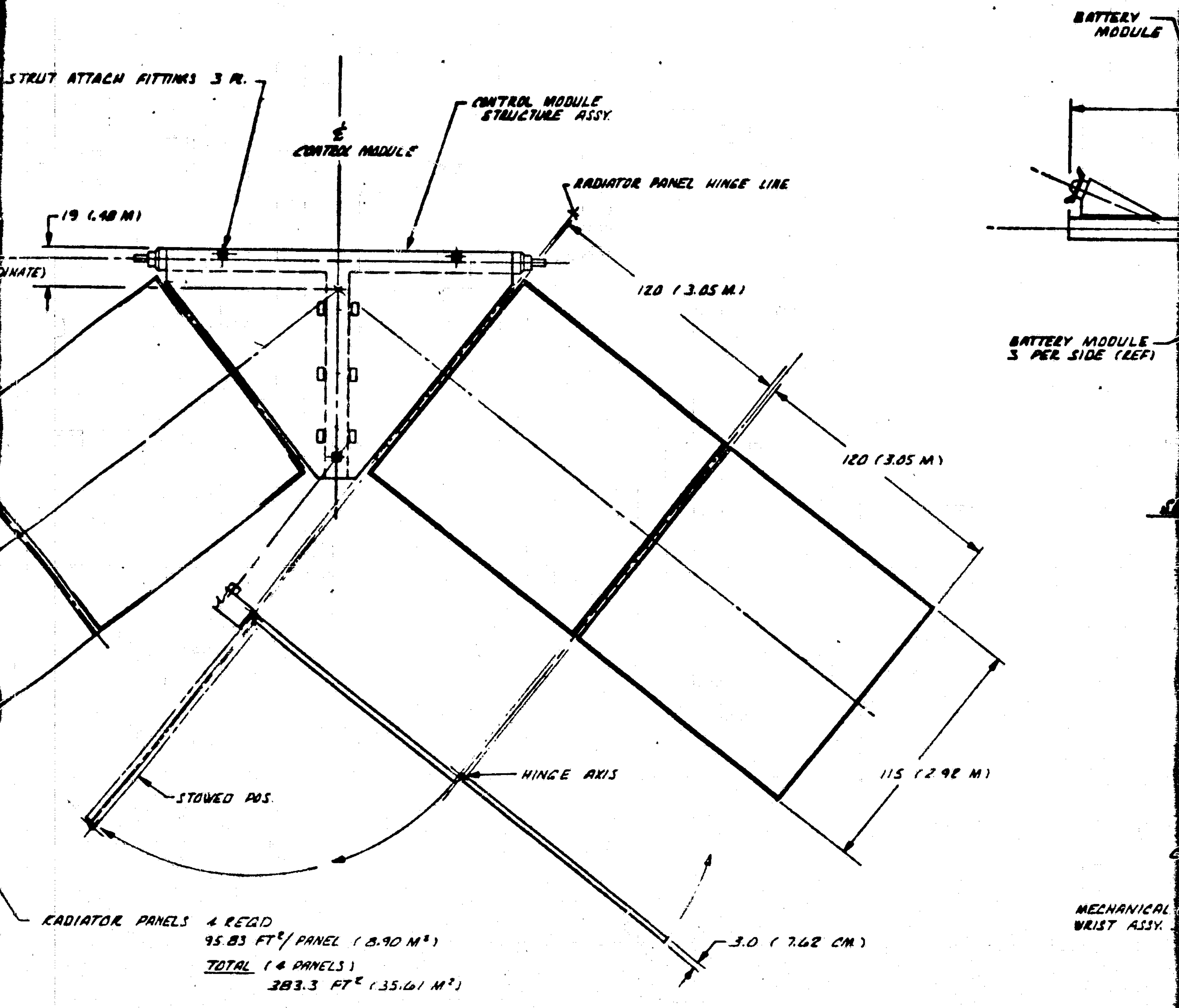
FOLDOUT FRAME



WIRE TRAY INSTALL CONFIG

2 FOLDOUT FRAME

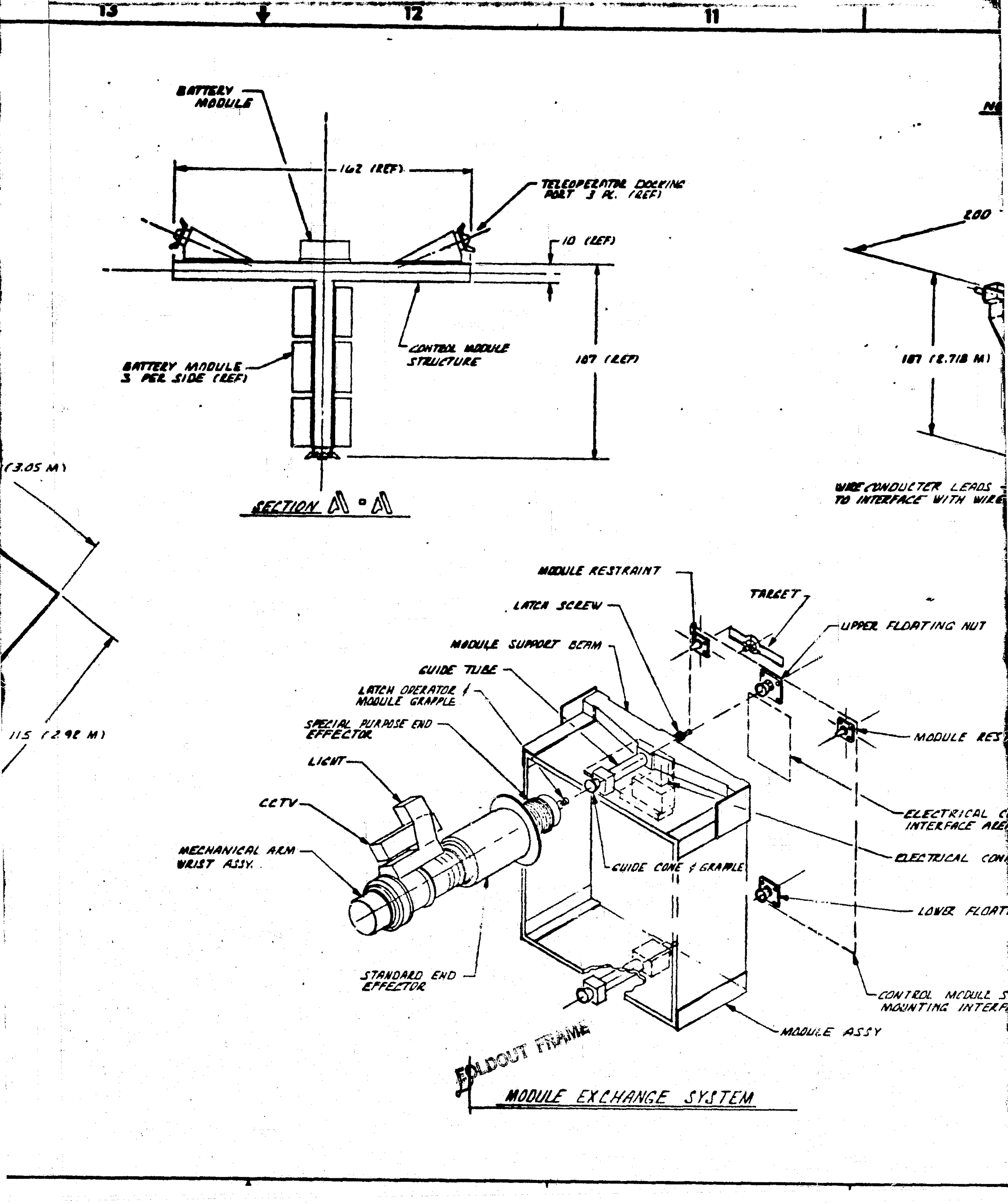
42662-57



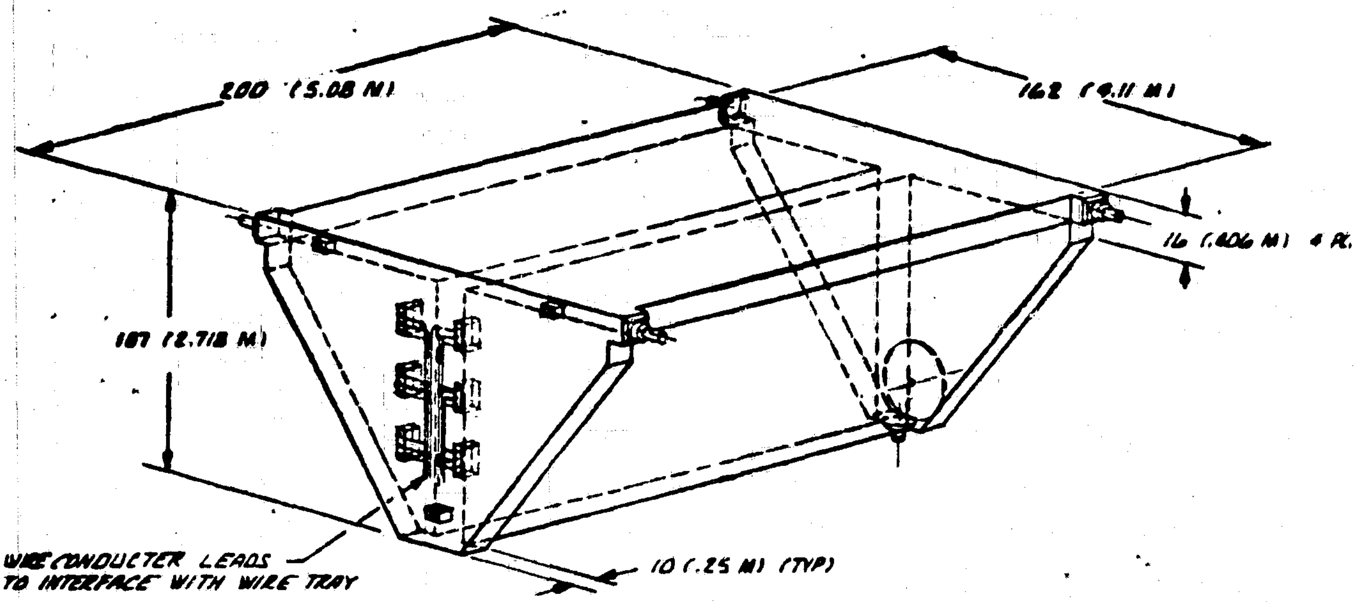
CONTROL MODULE - RADIATOR PANEL (S) CONFIG

3

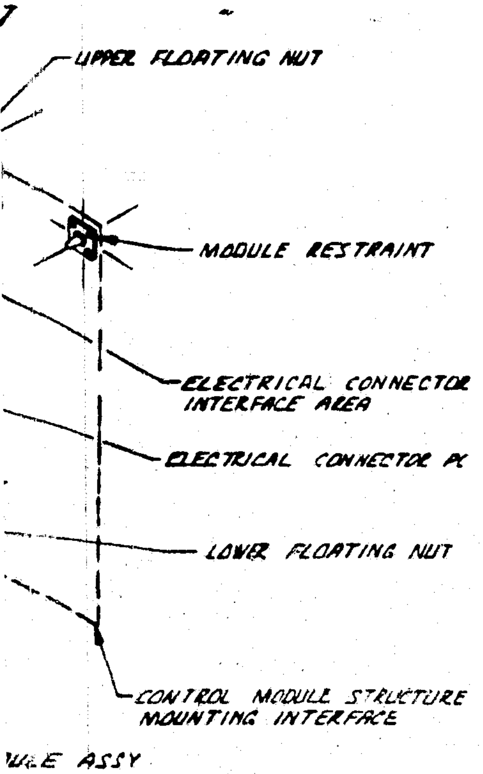
FOLDOUT FRAME


13
12
11
BATTERY MODULE
162 (REF)
TELEOPERATOR DOCKING PORT 3 PL. (REF)
10 (REF)
CONTROL MODULE STRUCTURE
BATTERY MODULE 3 PER SIDE (REF)
107 (REF)
SECTION A - A
200
107 (2.718 M)
(3.05 M)
115 (2.92 M)
WIRE CONDUCTER LEADS
TO INTERFACE WITH WIRE
MODULE RESTRAINT
TARGET
LATCH SCREW
UPPER FLOATING NUT
MODULE SUPPORT BEAM
GUIDE TUBE
LATCH OPERATOR & MODULE GRAPPLE
SPECIAL PURPOSE END EFFECTOR
MODULE RES
LIGHT
CCTV
ELECTRICAL C
INTERFACE ARE
MECHANICAL ARM WRIST ASSY.
ELECTRICAL CON
GUIDE CONE & GRAPPLE
LOWER FLOAT
STANDARD END EFFECTOR
CONTROL MODULE S
MOUNTING INTERF
MODULE ASSY
FOLDOUT FRAME
MODULE EXCHANGE SYSTEM

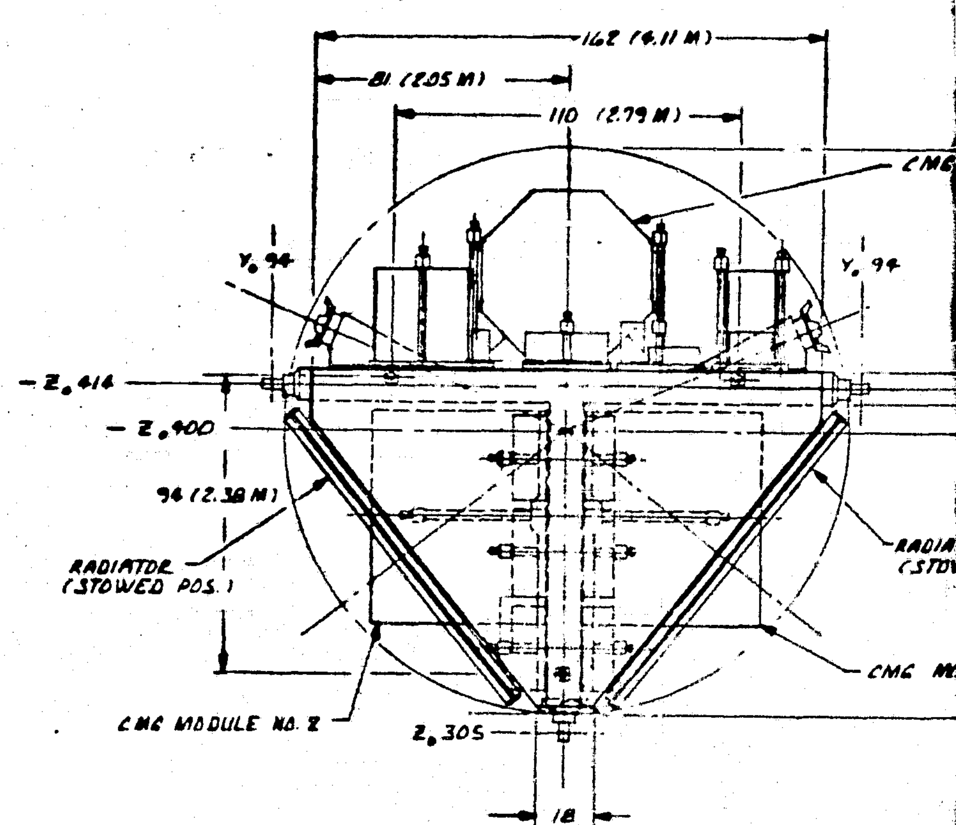
NOTE: UPPER DECK PLATFORM SHOWN AND BOTH SIDES OF VERTICAL WEB ARE COLD PLATE SURFACES



CONTROL MODULE STRUCTURE CONFIG



...URE ASSY



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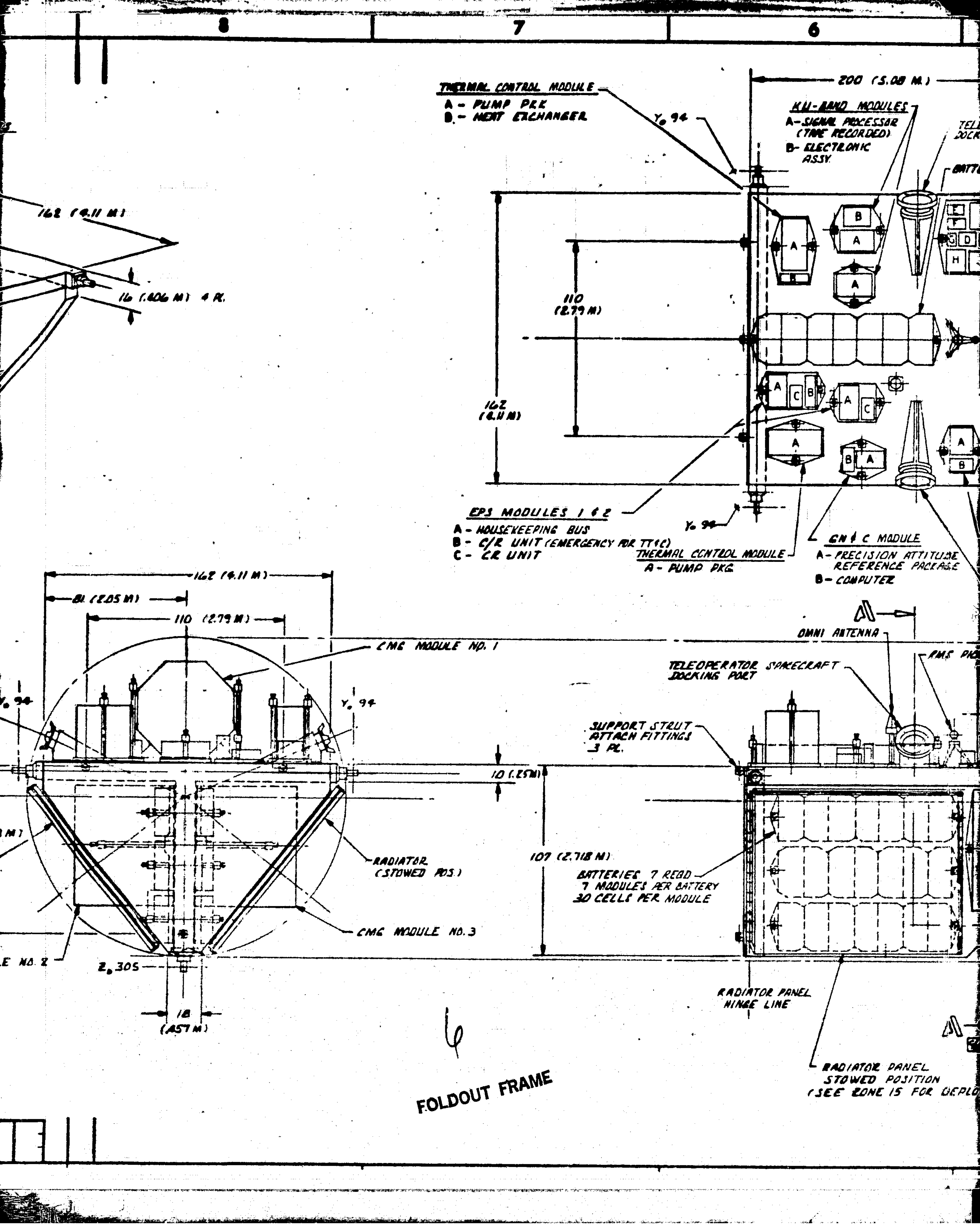
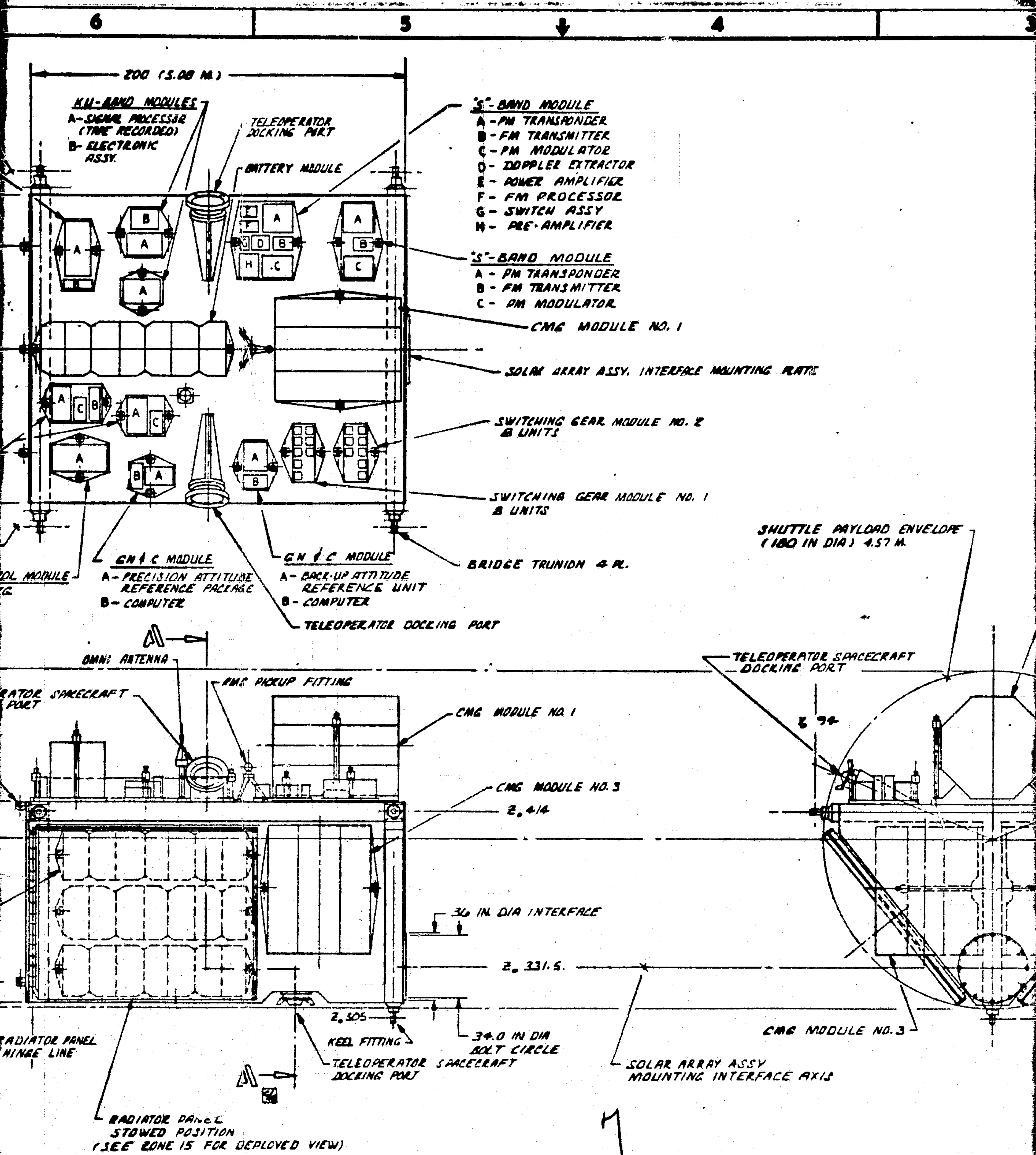
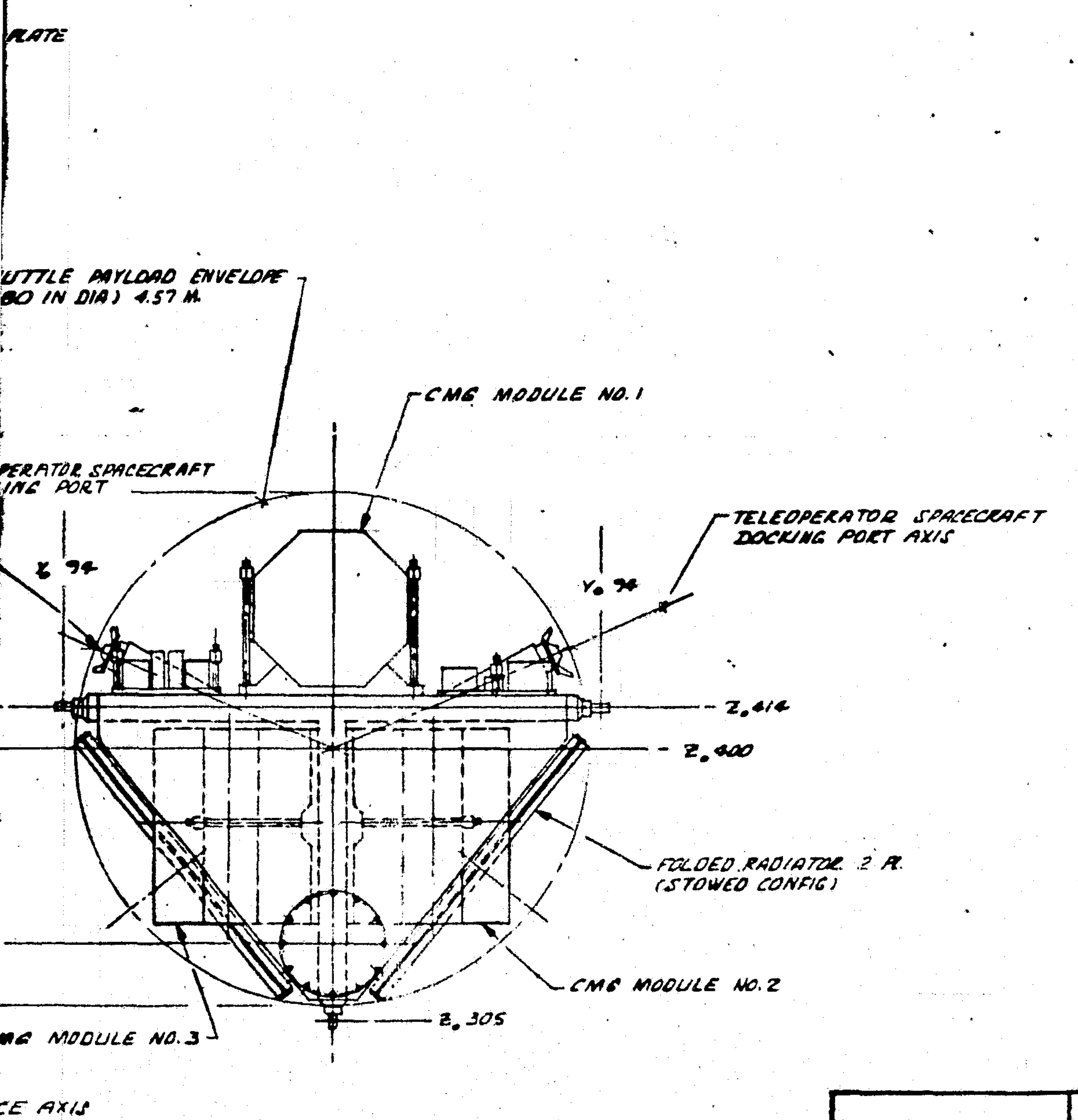

8
7
6
THERMAL CONTROL MODULE
A - PUMP PKG
B - HEAT EXCHANGER
200 (5.08 M)
KU-BAND MODULES
A - SIGNAL PROCESSOR (TAPE RECORDED)
B - ELECTRONIC ASSY
162 (4.11 M)
16 (.406 M) 4 PL
110 (2.79 M)
162 (4.11 M)
EPS MODULES 1 & 2
A - HOUSEKEEPING BUS
B - C/R UNIT (EMERGENCY FOR TT&C)
C - CR UNIT
THERMAL CONTROL MODULE
A - PUMP PKG
GN & C MODULE
A - PRECISION ATTITUDE REFERENCE PACKAGE
B - COMPUTER
162 (4.11 M)
81 (2.05 M)
110 (2.79 M)
CMG MODULE NO. 1
OMNI ANTENNA
TELEOPERATOR SPACECRAFT DOCKING PORT
SUPPORT STRUT ATTACH FITTINGS 3 PL.
10 (.25 M)
RADIATOR (STOWED POS.)
107 (2.718 M)
BATTERIES 7 REQD
7 MODULES PER BATTERY
30 CELLS PER MODULE
CMG MODULE NO. 3
Z. 305
18 (.457 M)
RADIATOR PANEL HINGE LINE
RADIATOR PANEL STOWED POSITION (SEE ZONE 15 FOR DEPLO
6
FOLDOUT FRAME



FOLDOUT FRAME

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED



A-25,
A-26

FOLDOUT FRAME

DR BY	[signature]	12-14-7?
CHK BY		
APPROVED BY		

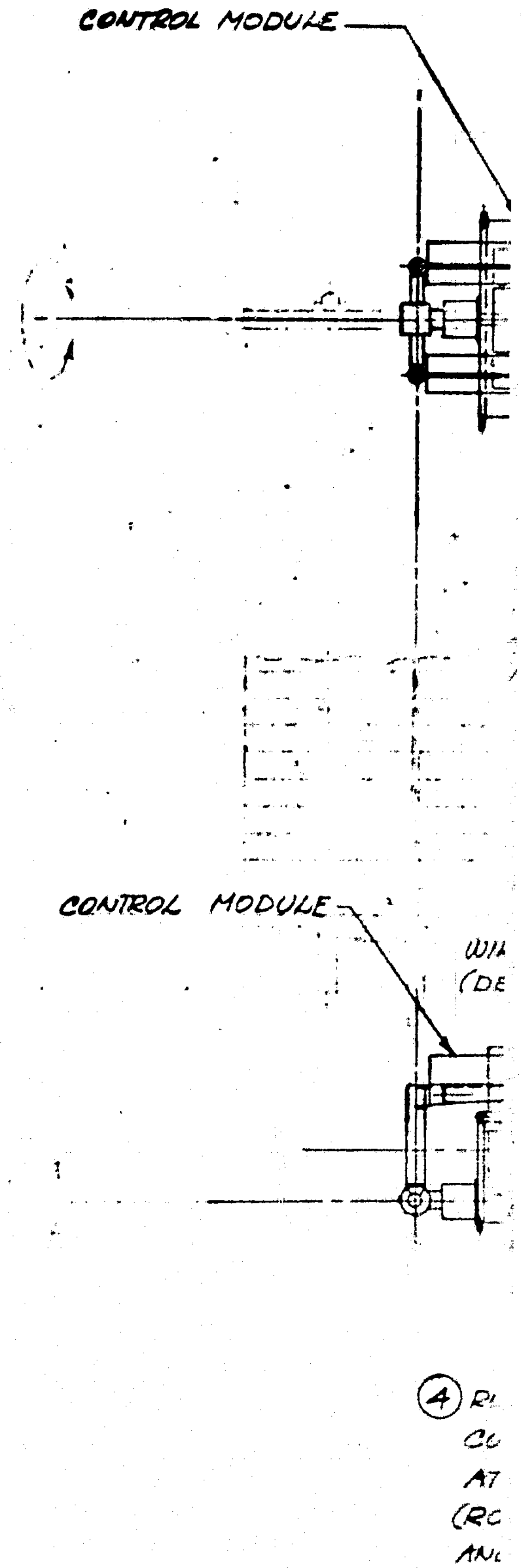
Rockwell International Corporation
Space Division
12214 Lakewood Boulevard • Downey California 90241

CONTROL MODULE ASSY-
ENGINEERING & TECHNOLOGY
VERIFICATION PLATFORM

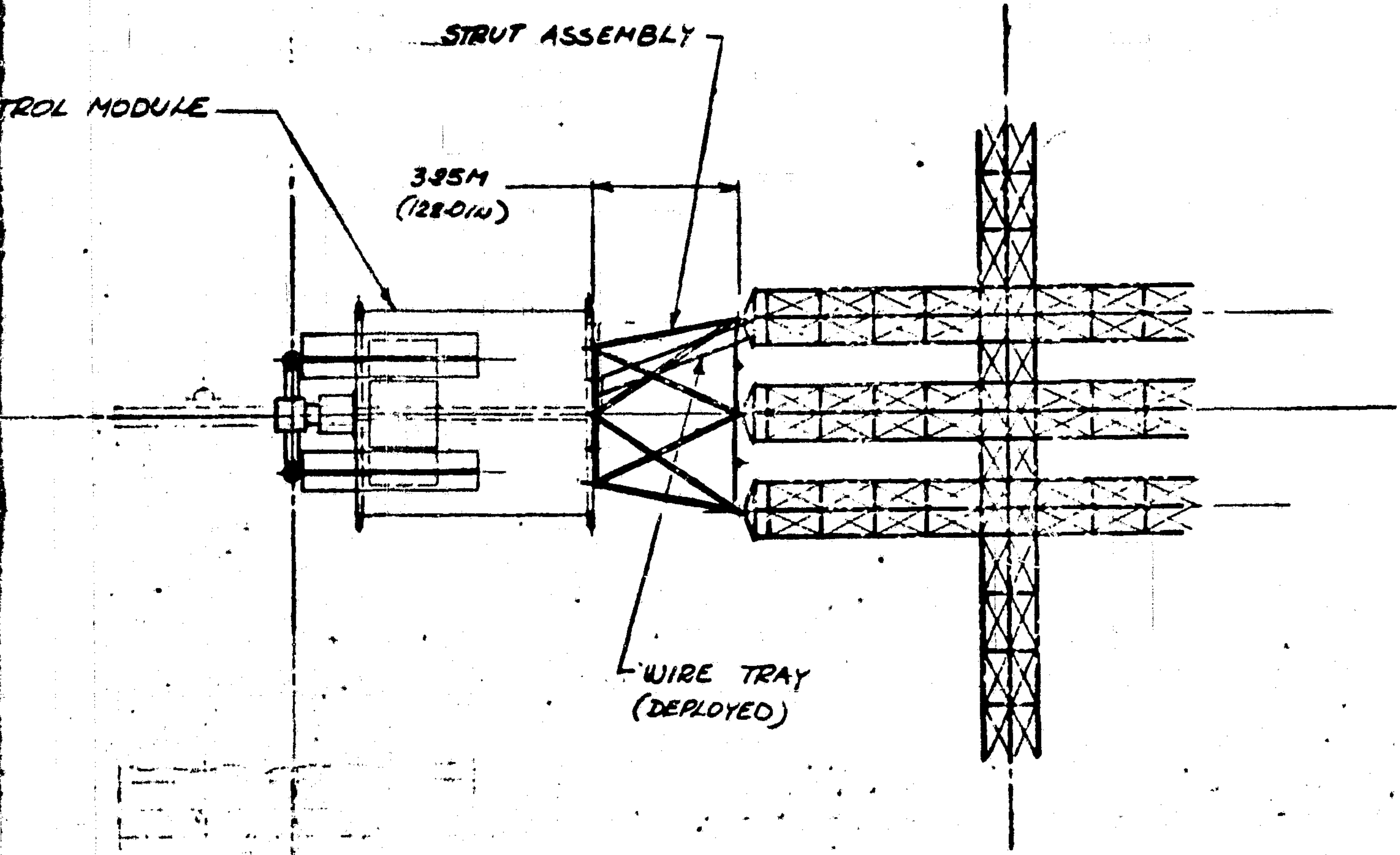
SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662-57

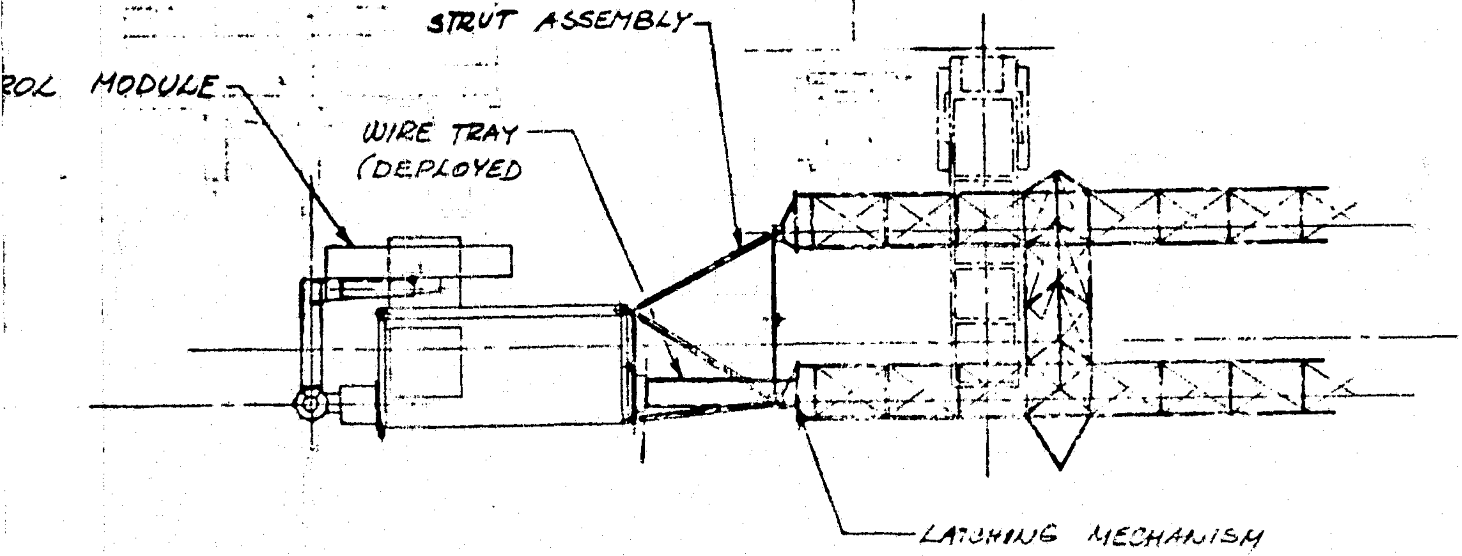
SCALE | SHEET

42662-57



FOLDOUT FRAME

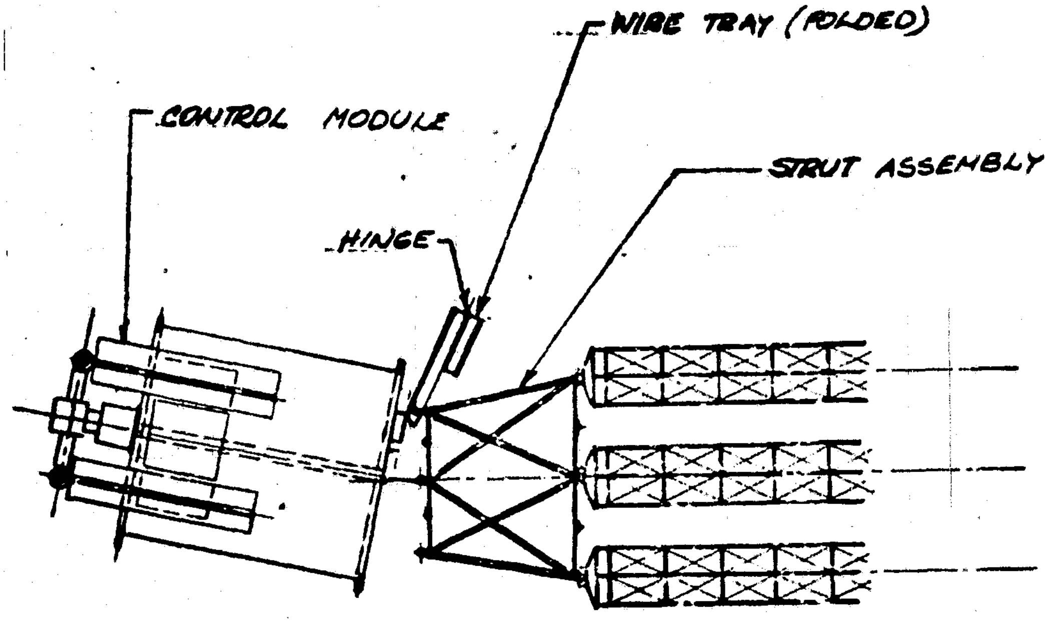


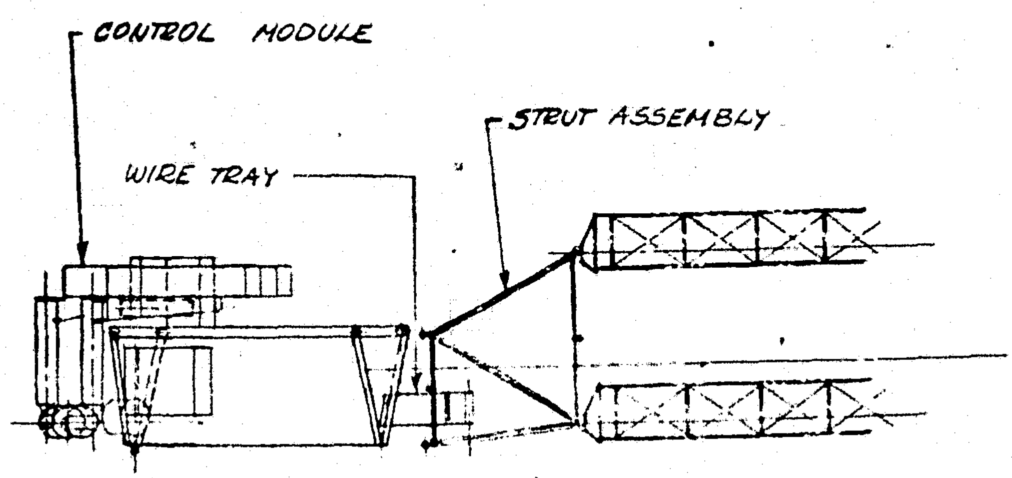


(4) ROTATE CONTROL MODULE WITH RMS AND ATTACH CONTROL MODULE TO TWO REMAINING BALL ATT. HOUSING.
(ROTATE CABLE TRAY TO OPERATING POSITION AND LATCH END OF CABLE TRAY TO FABRICATED BEAM)

2

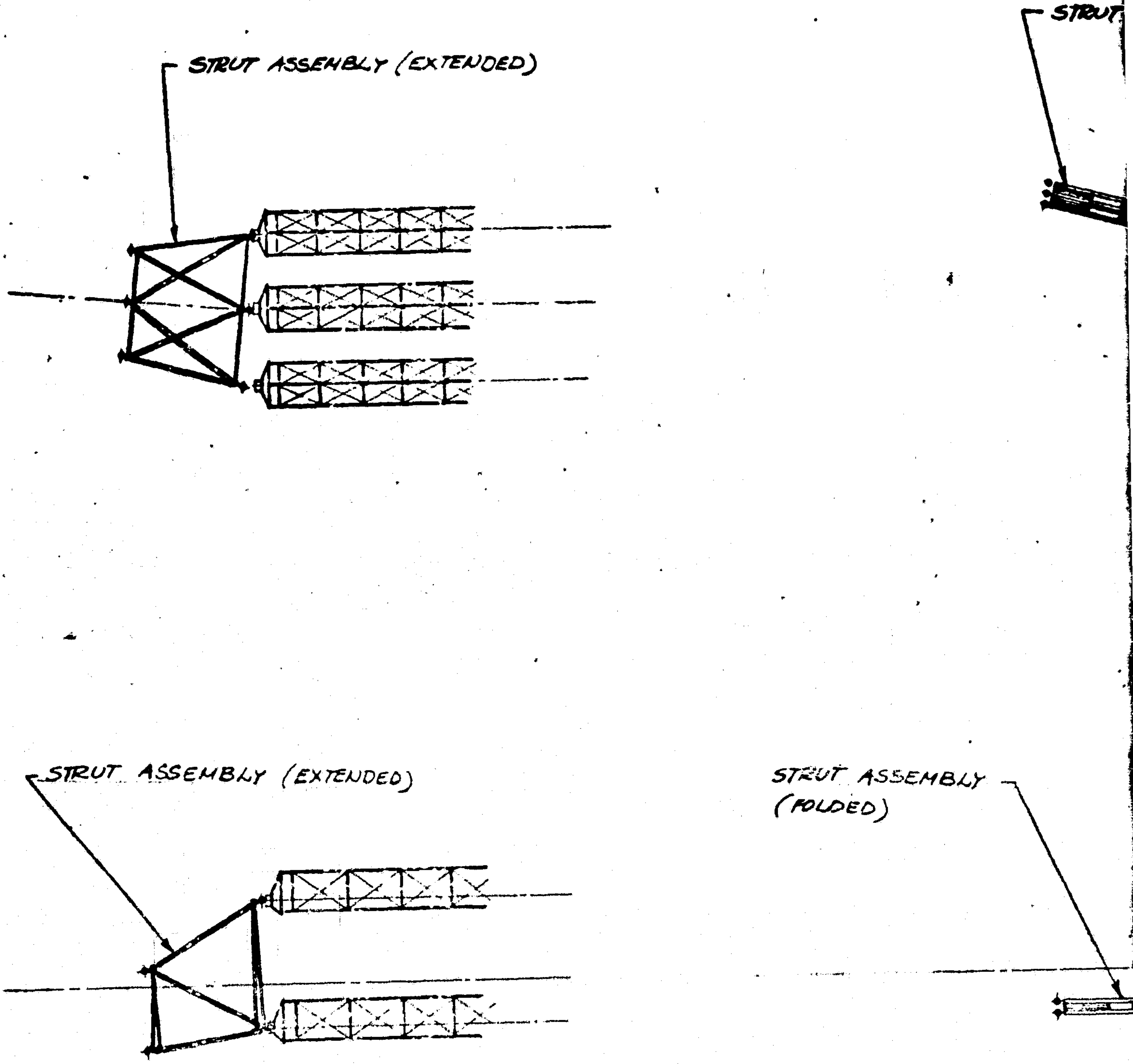
FOLDOUT FRAME





(3) CONTROL MODULE ATTACH WITH RMS TO ONE BALL END ATT. HOUSING OF STRUT ASSEMBLY INSTLLATION. (ROTATE CABLE TRAY TO CLEAR STRUT ASSEMBLY INSTALLATION)

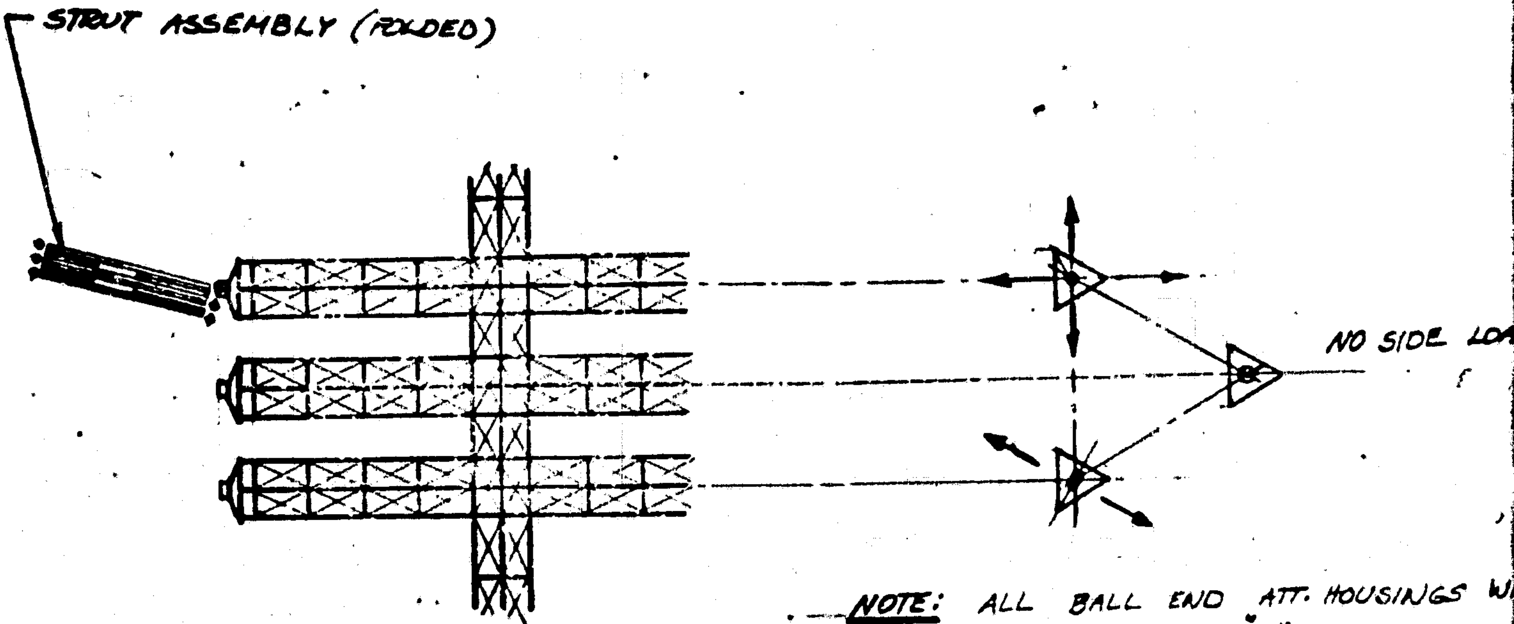
FOLDOUT FRAME



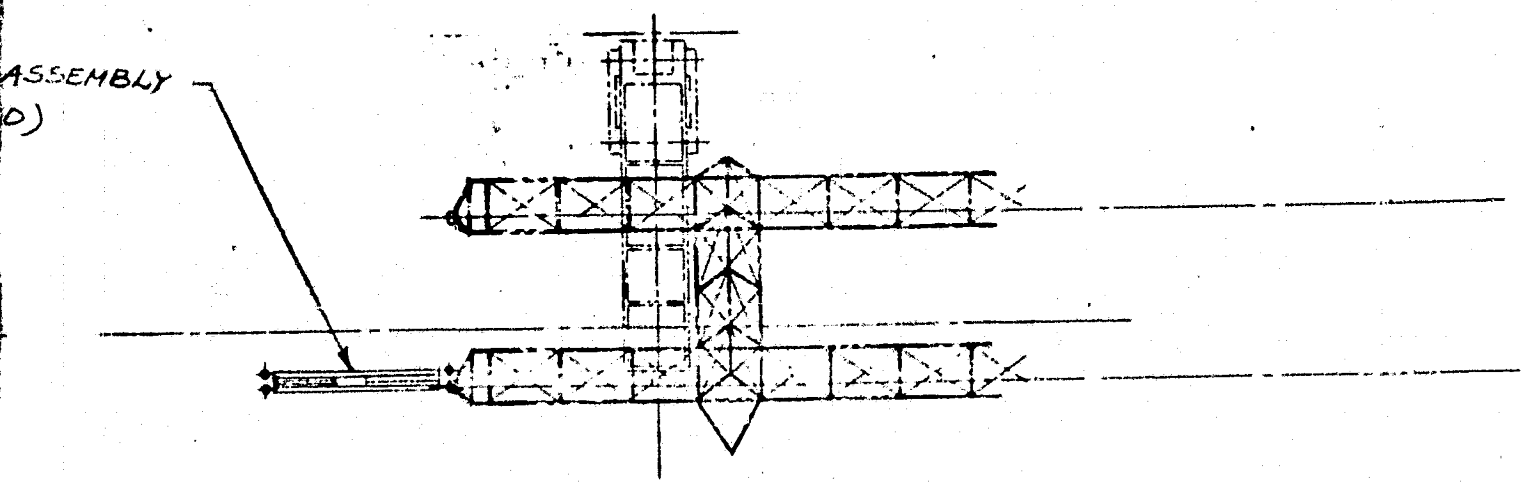
(2) EXTENDED STRUT ASSEMBLY ATTACH WITH RMS
TO REMAINNING TWO BALL ATT. HOUSINGS

4.

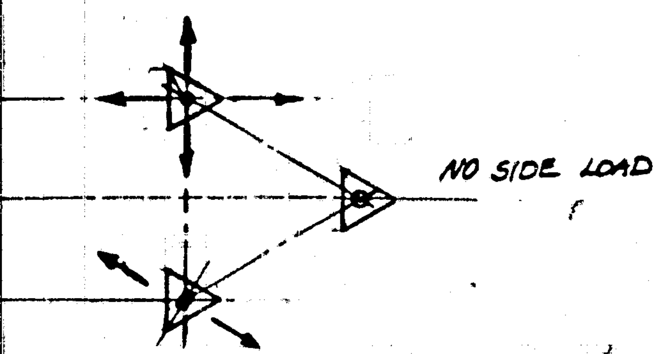
FOLDOUT FRAME



NOTE: ALL BALL END ATT. HOUSINGS WI
TAKE LOAD ON "X" AXIS



(1) FOLDED STRUT ASSEMBLY ATTACH
WITH RMS AT ONE BALL ATT. HOUSING



TE: ALL BALL END ATT. HOUSINGS WILL TAKE LOAD ON "X" AXIS

SHT 1 OF 3

A-27, A-28

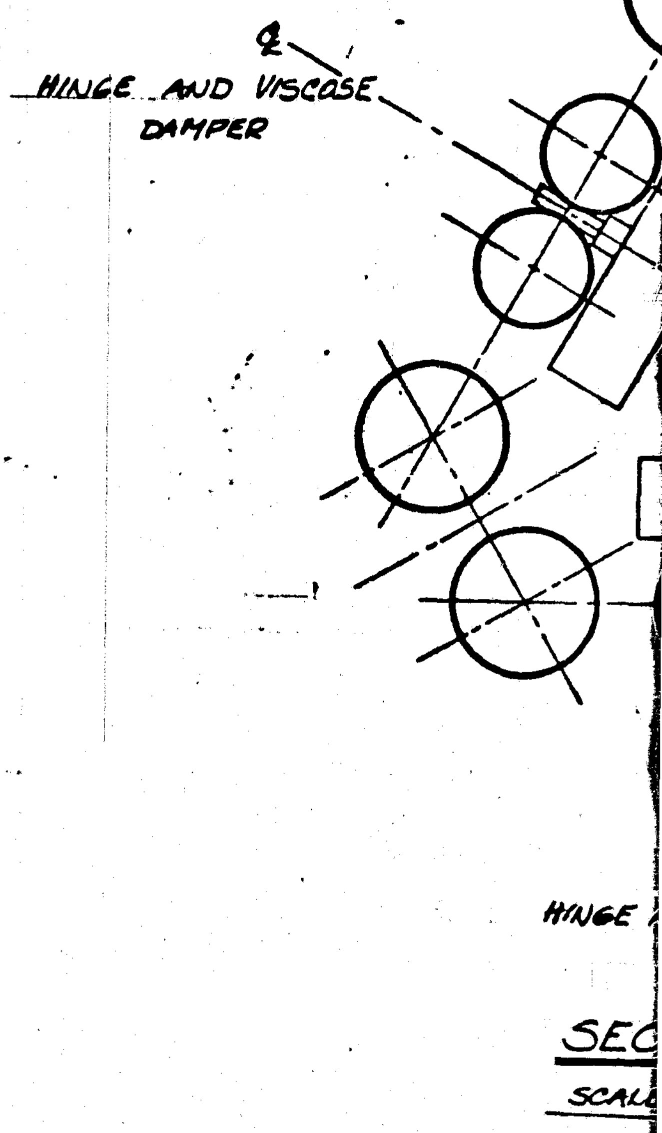
FOLDOUT FRAME

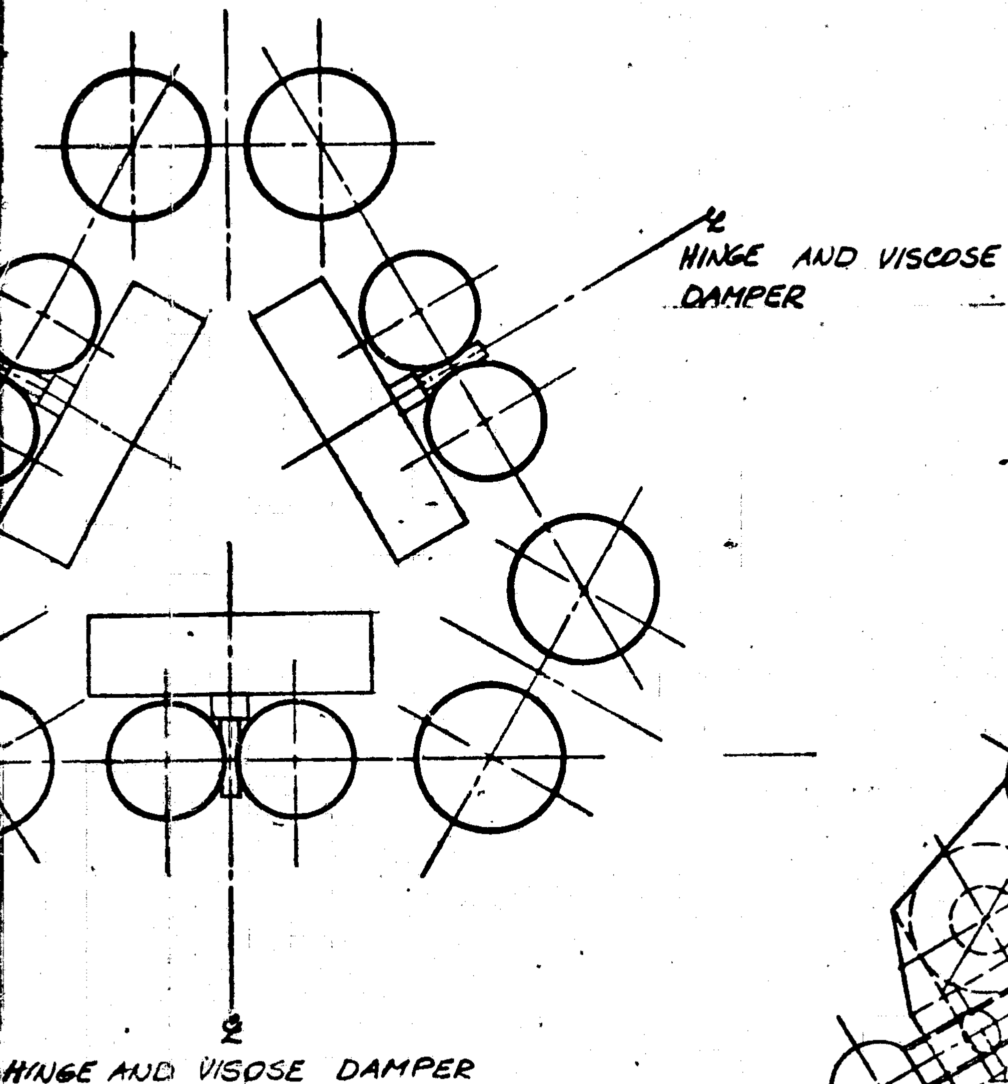
Rockwell International

FORWARD ASSEMBLY AND INSTALLATION

42662-59

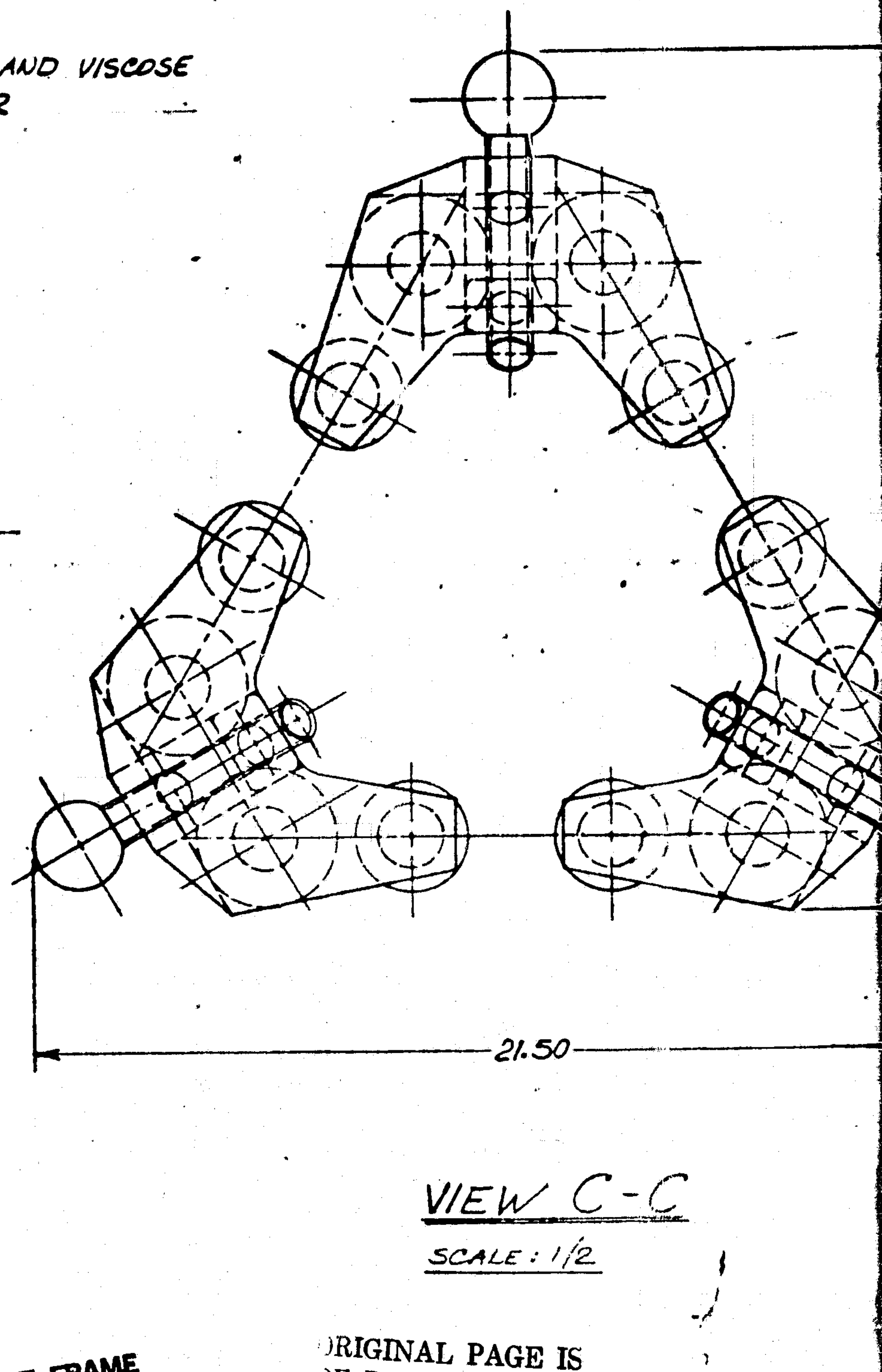
C-5





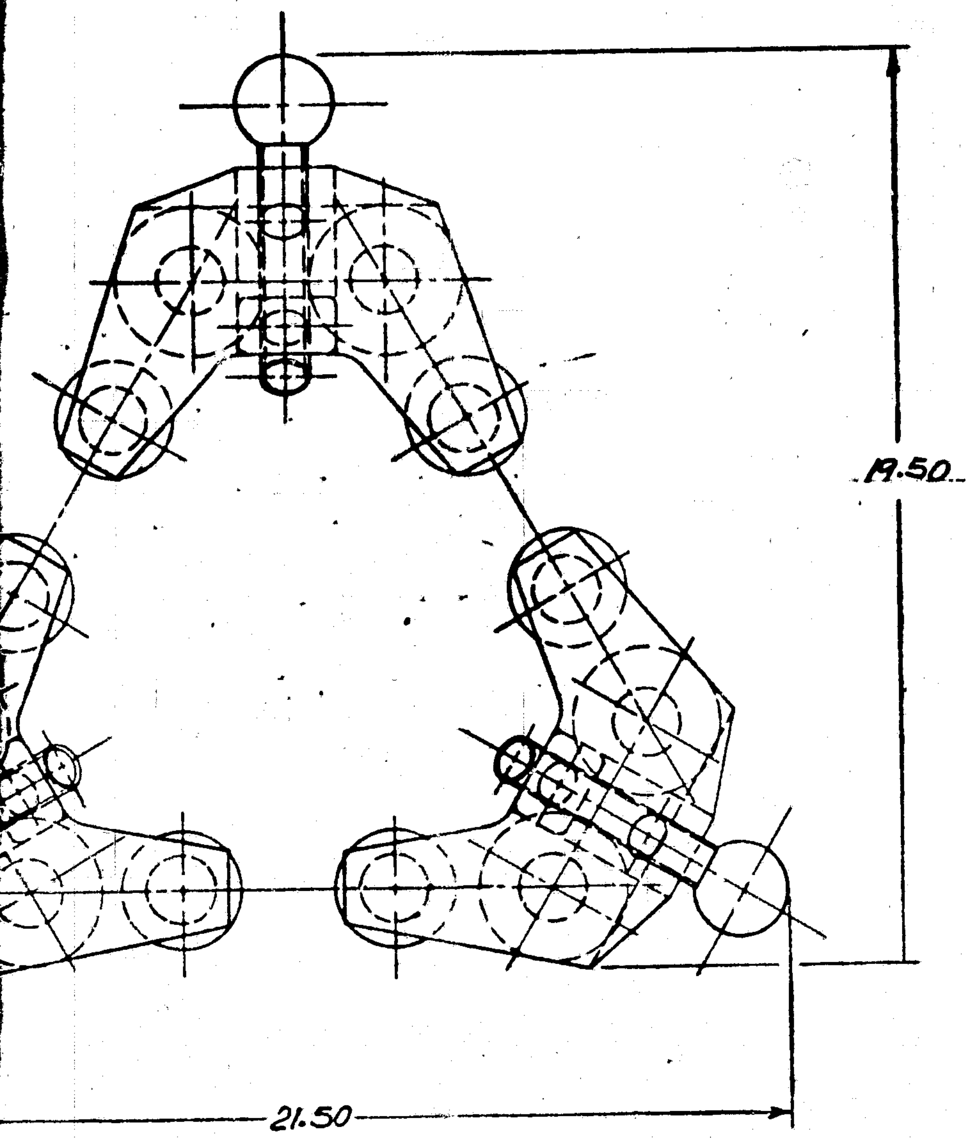
SECTION D-D

SCALE: 1/2



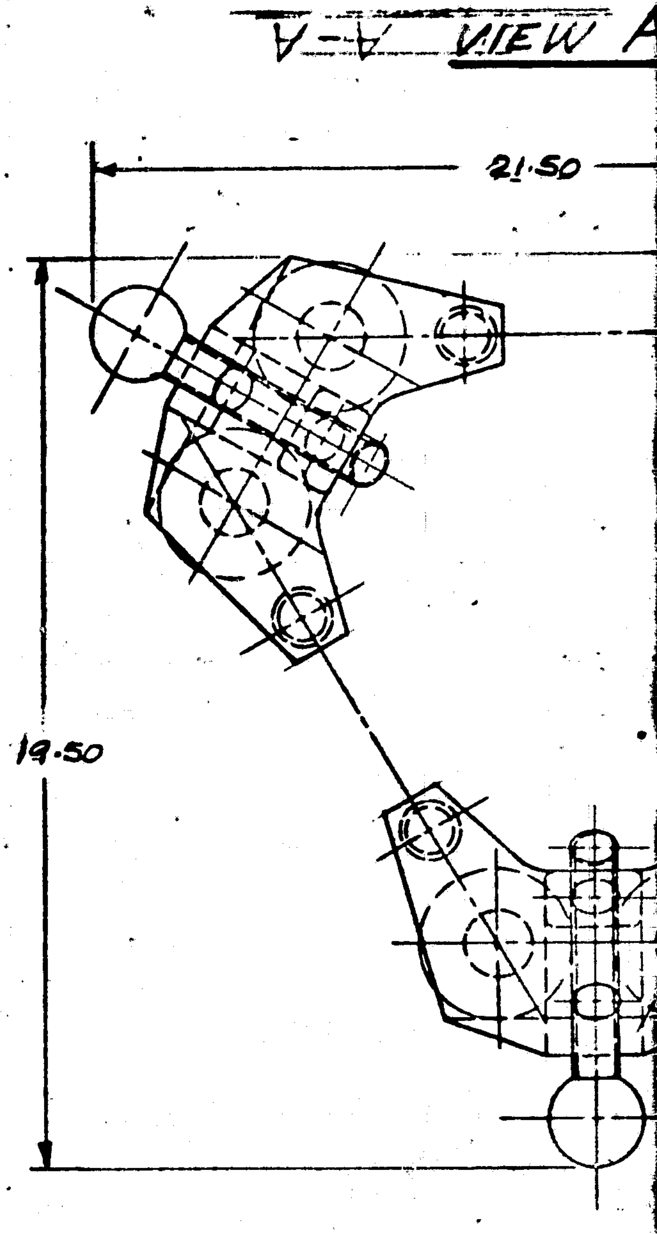
VIEW C-C

SCALE: 1/2



VIEW C-C

SCALE: 1/2

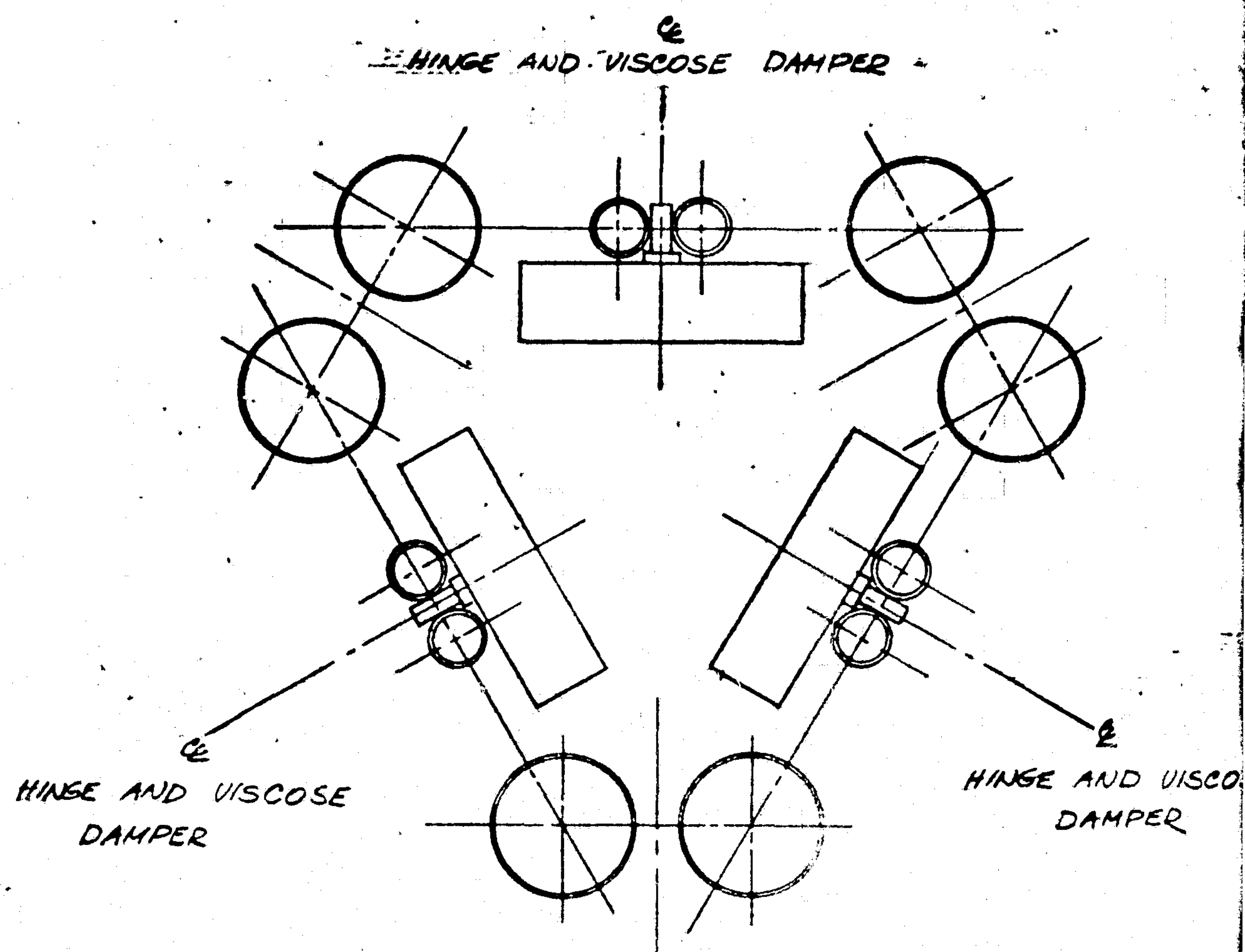


ORIGINAL PAGE IS
OF POOR QUALITY

3 FOLDOUT FRAME

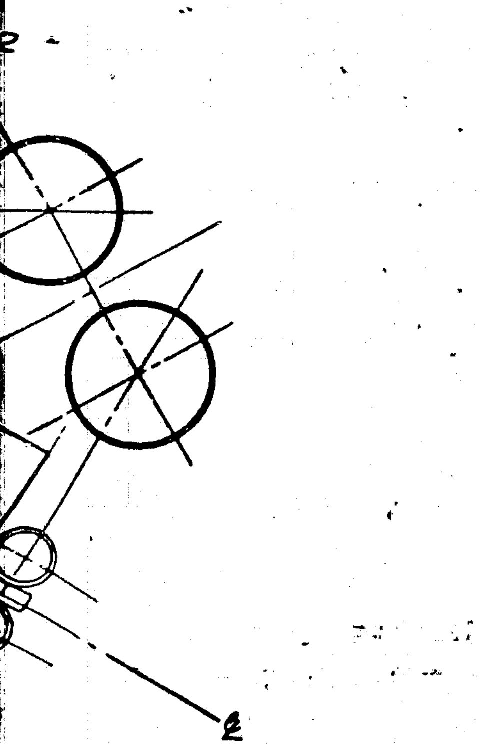
A - SCALE: 1/2

SECTION B-B - SCALE: 1/2

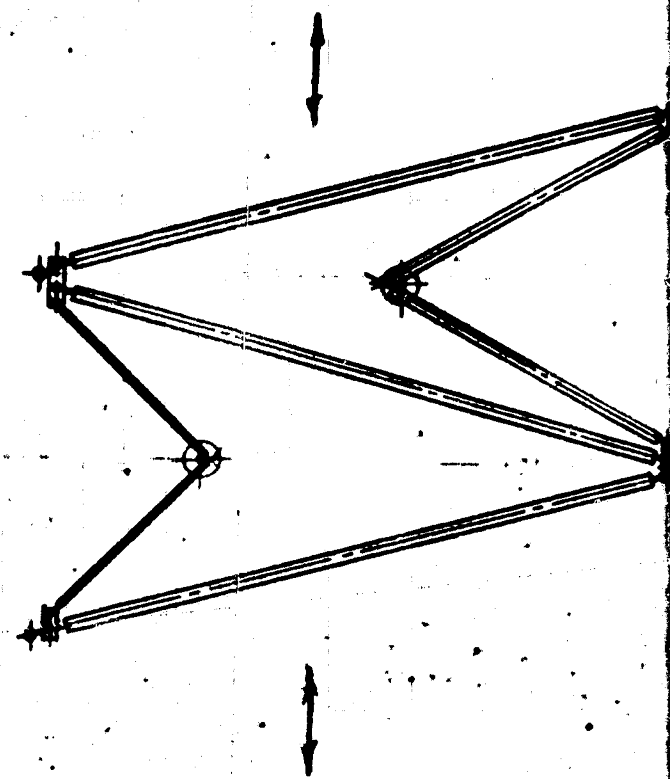


ORIGINAL PAGE IS
OF POOR QUALITY

SCALE :1/2

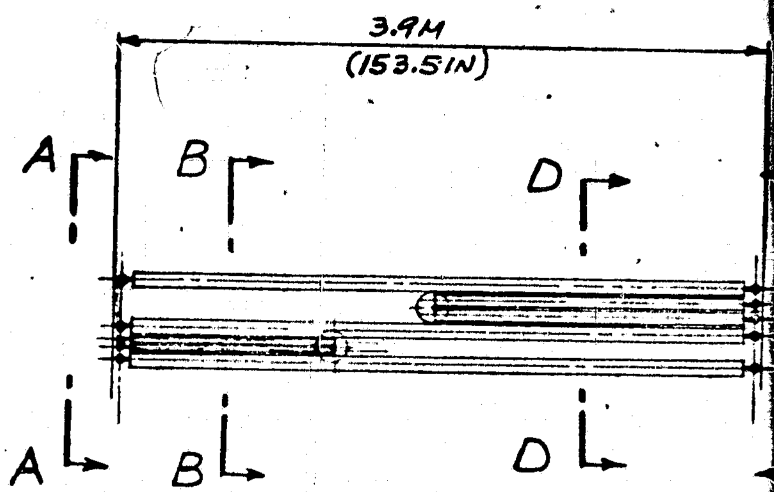


HINGE AND VISCOSE DAMPER



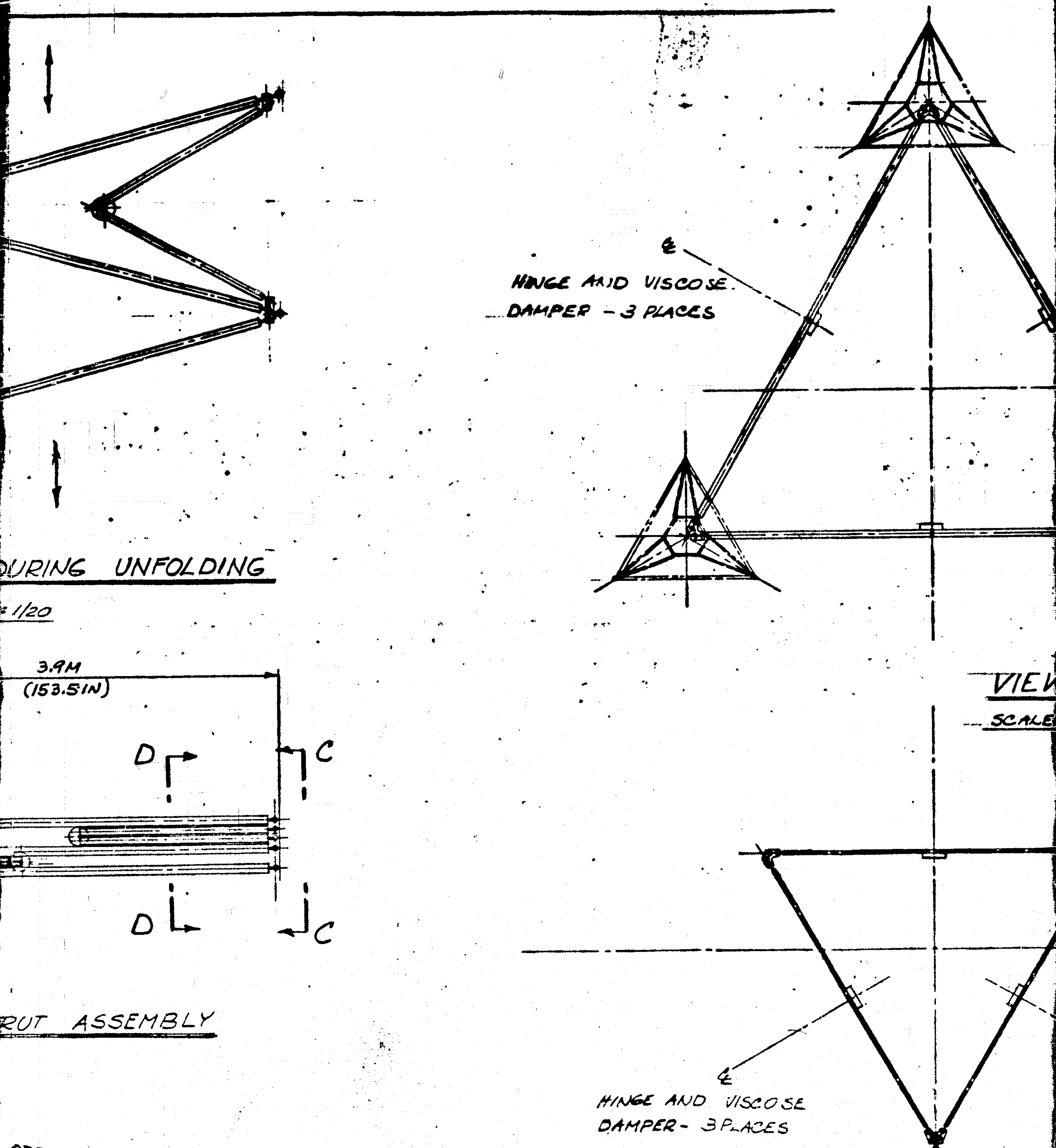
STRUT DURING UNFOLDING

SCALE : 1/20

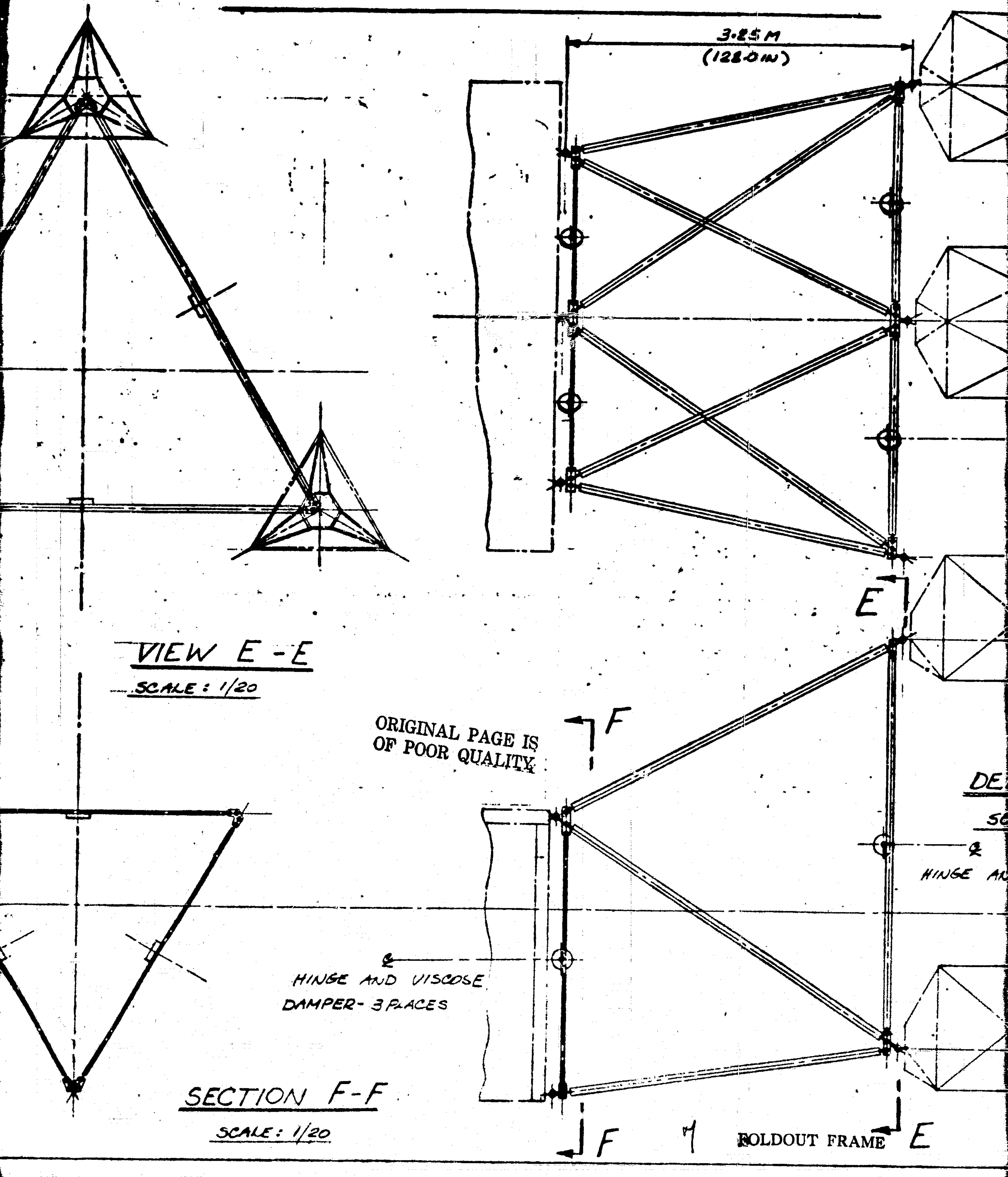


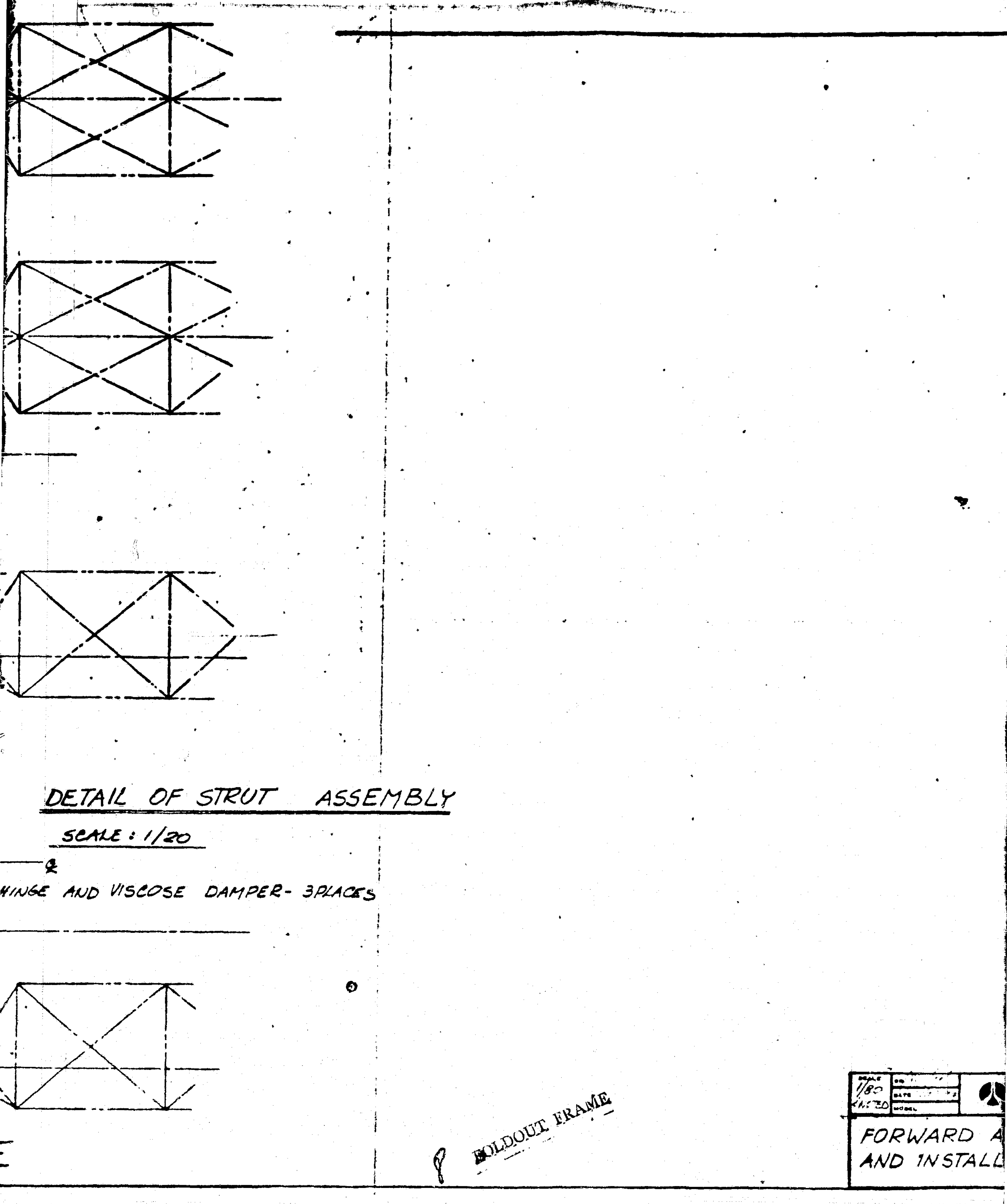
FOLDED STRUT ASSEMBLY

SCALE : 1/20


URING UNFOLDING
1/20
3.9M
(153.5IN)
D
C
D
C
RUT ASSEMBLY
HINGE AND VISCOSE
DAMPER - 3 PLACES
VIEV
SCALE
HINGE AND VISCOSE
DAMPER- 3 PLACES

6


3.25 M
(128.0 IN)
E
VIEW E-E
SCALE: 1/20
F
DE
SC
HINGE AN
HINGE AND VISCOSE
DAMPER- 3 PLACES
SECTION F-F
SCALE: 1/20
F
E



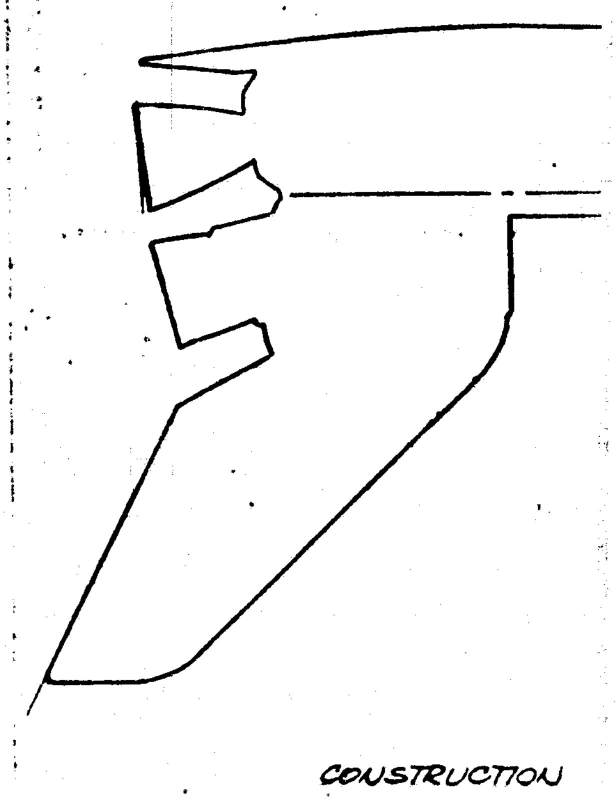
FOLDOUT FRAME

9 FOLDOUT FRAME

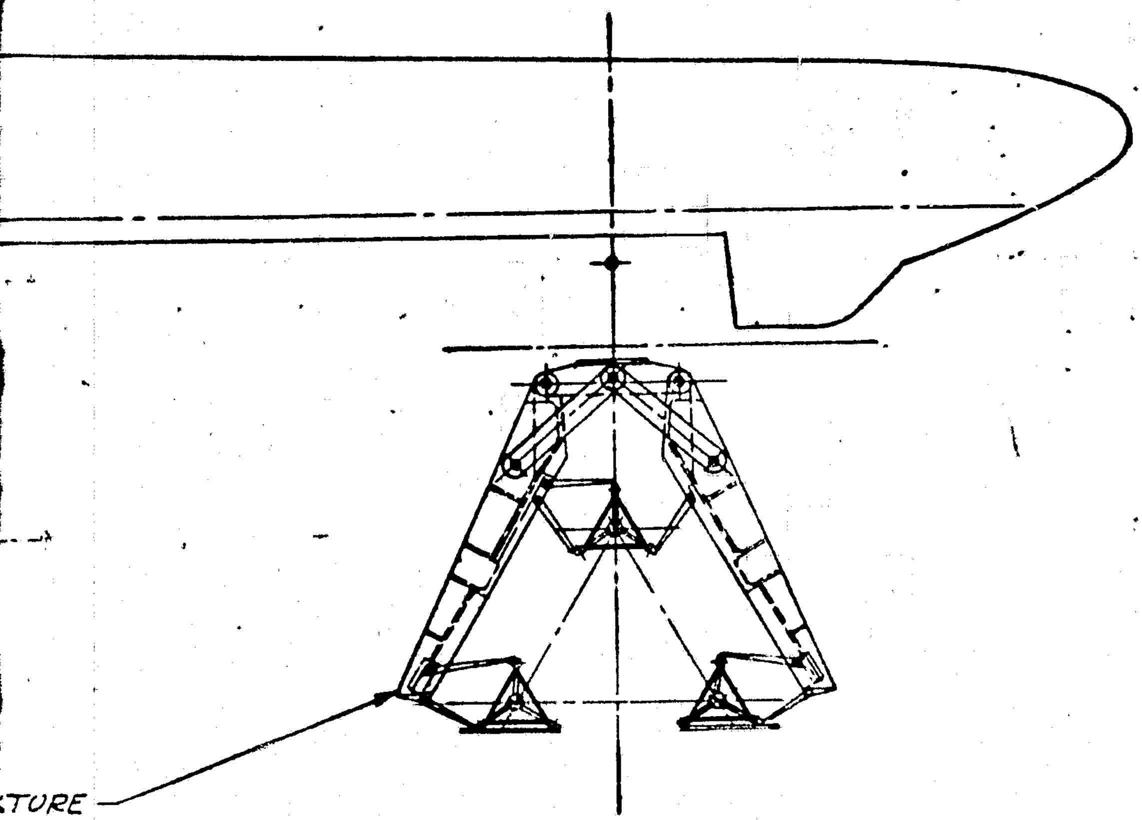
SHT 2 OF 3

A-29, A-30

SCALE 1/80 NOTED	BY / DATE / MODEL	Rockwell International	
FORWARD ASSEMBLY AND INSTALLATION			42662-59

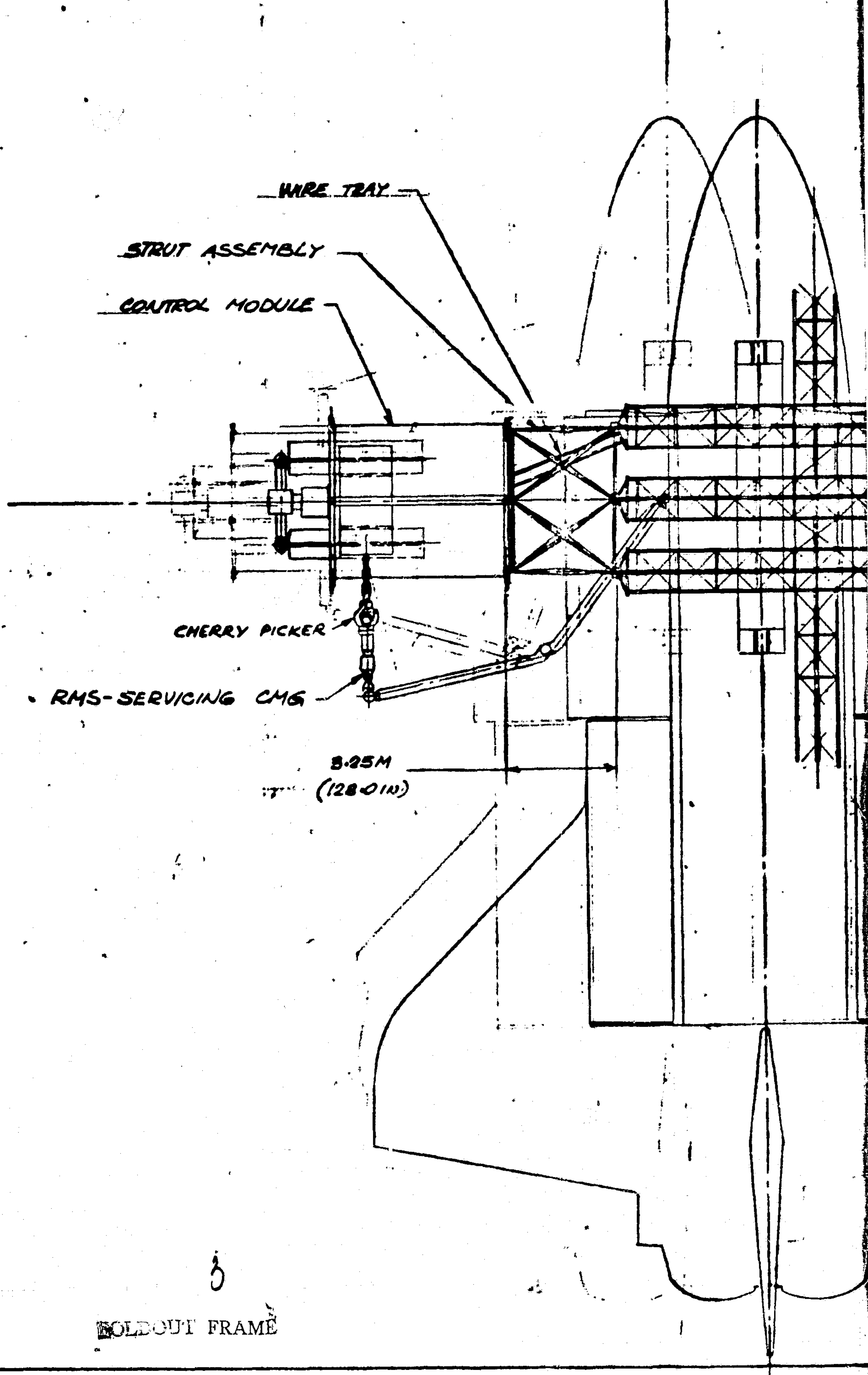


FOLDOUT FRAME 1



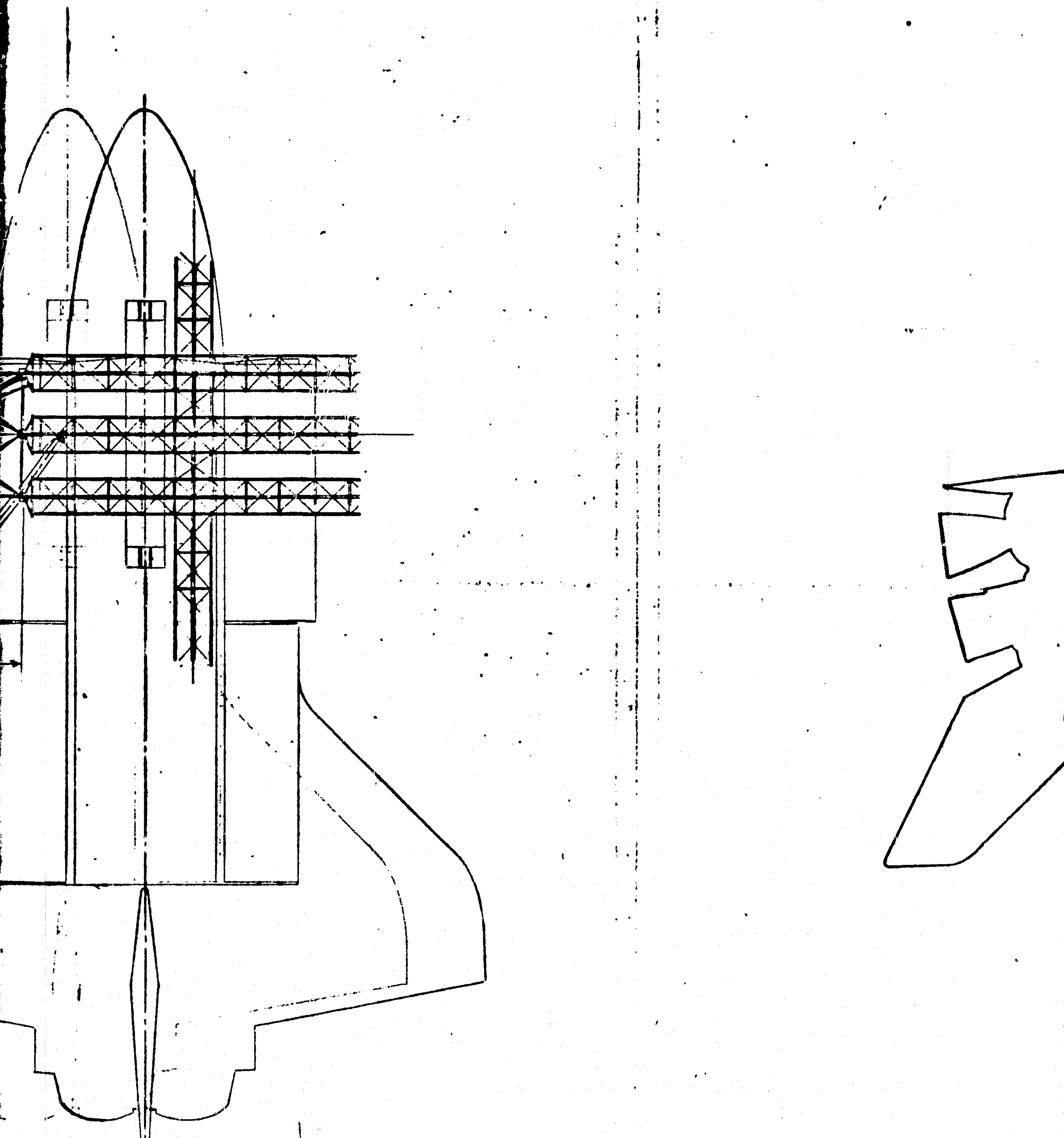
SECTION G - G

2 FOLDOUT FRAME

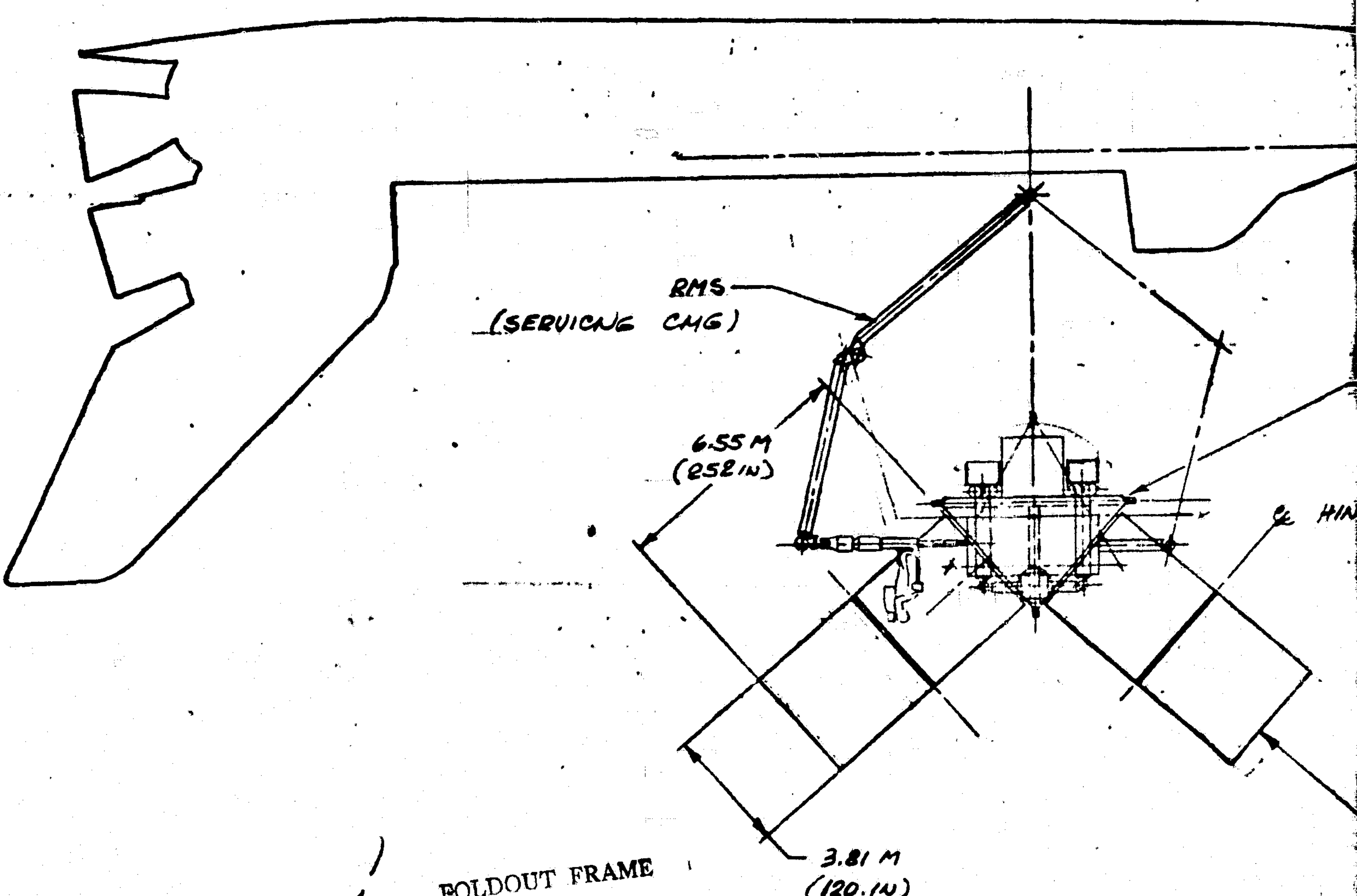


3

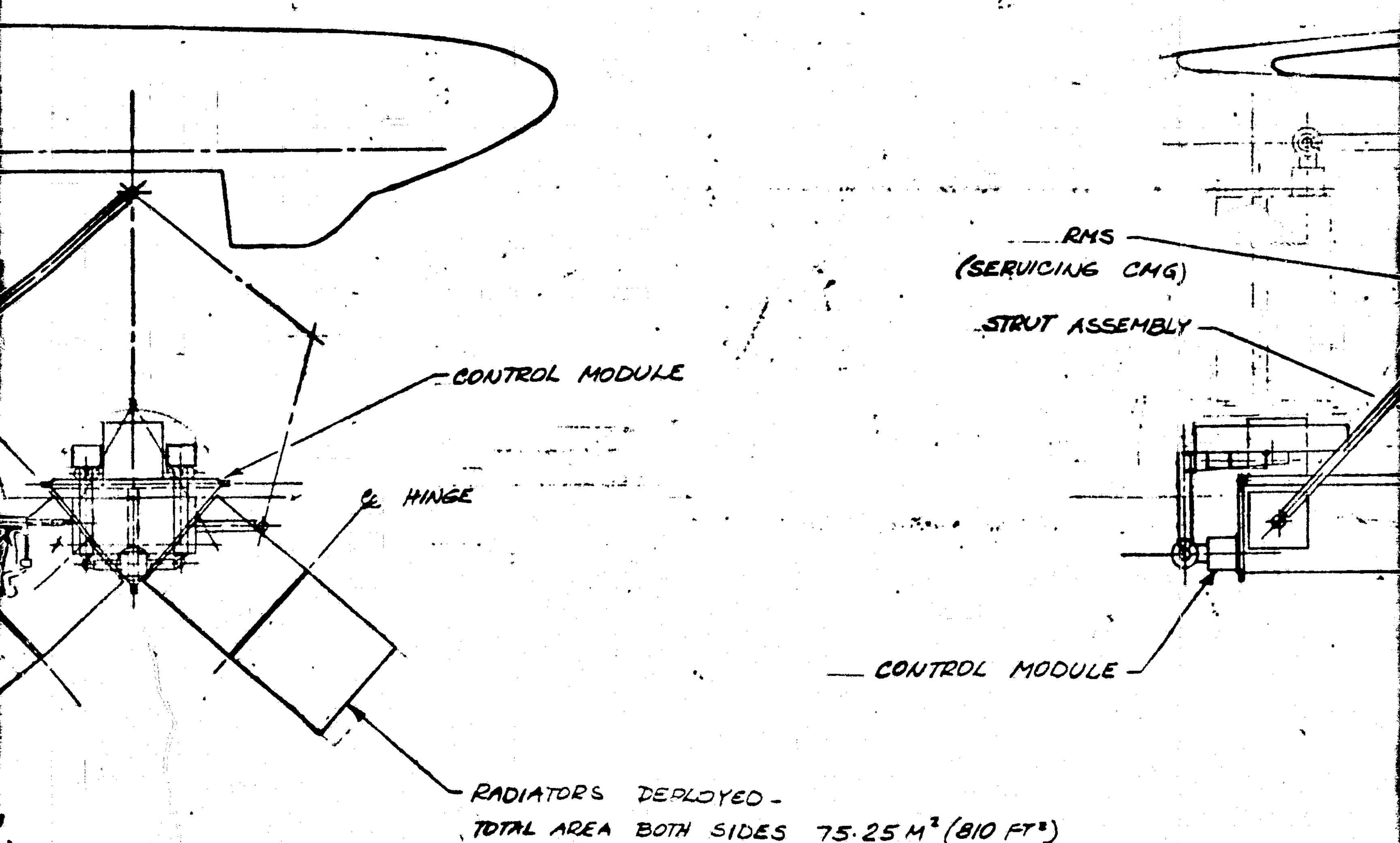
FOLDOUT FRAME



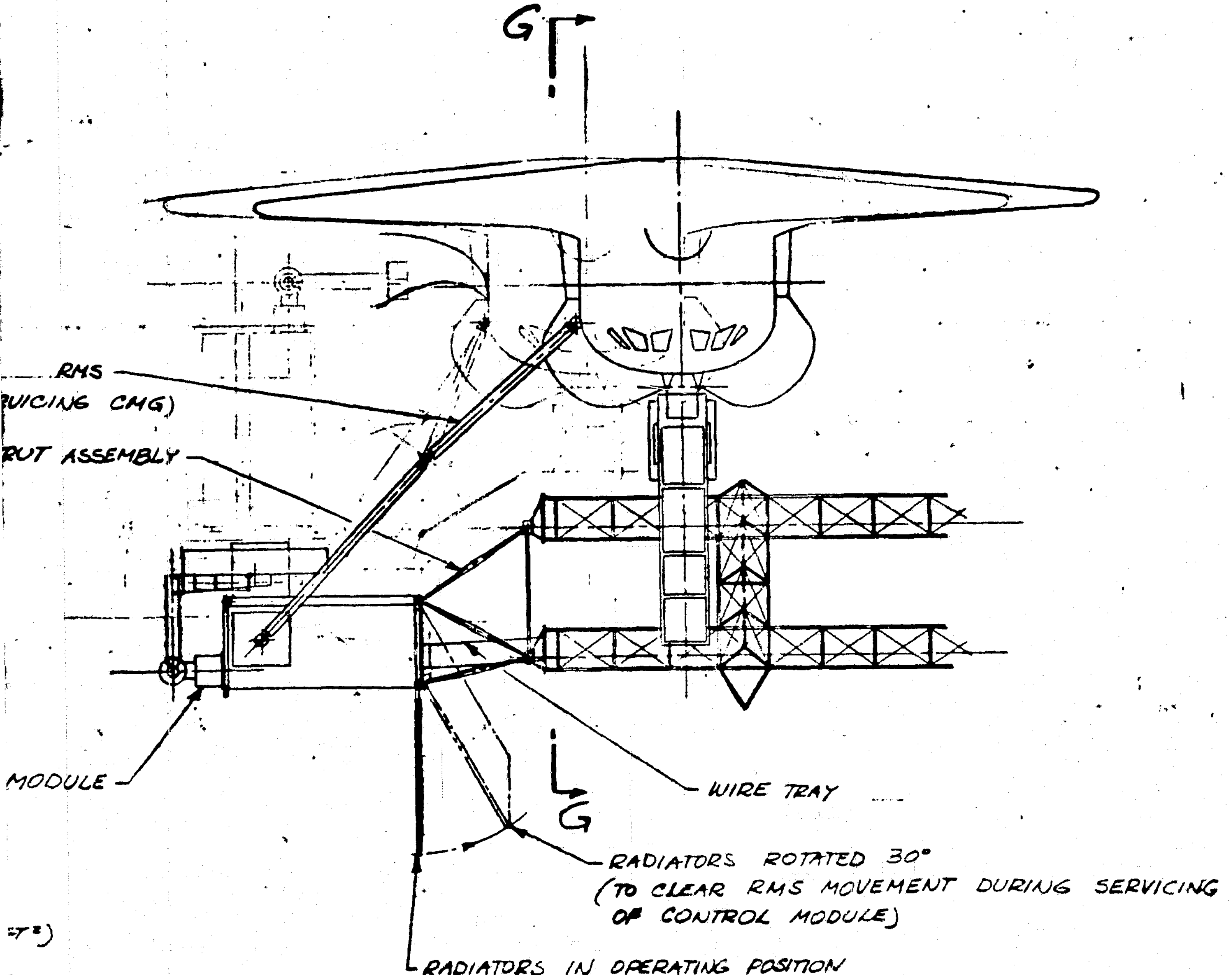
4 FOLDOUT FRAME



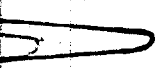
FOLDOUT FRAME



6 FOLDOUT FRAME



4 FOLDOUT FRAME



DURING SERVICING

8 FOLDOUT FRAME

SHT 3 OF 3
A-31,
A-32

Rockwell International

FORWARD ASSEMBLY
AND INSTALLATION

42662-59

24

D

C

(B) LANYARD; PU
RELEASE LA
FOR ALL LA

GRASP POINT FOR RMS

B

(B)

(B) THE ELEMENTS OF THE STRUCTURE ARE SECURED TOGETHER BY MECHANICAL LATCHES, THE RELEASE OF WHICH IS INITIATED MANUALLY BY AN EVA ASTRONAUT

CENTRAL FRAMES 7, 8 & 9 ARE DEPLOYED BY THE SPRING LOADED CYLINDERS SHOWN IN ZONE 11.

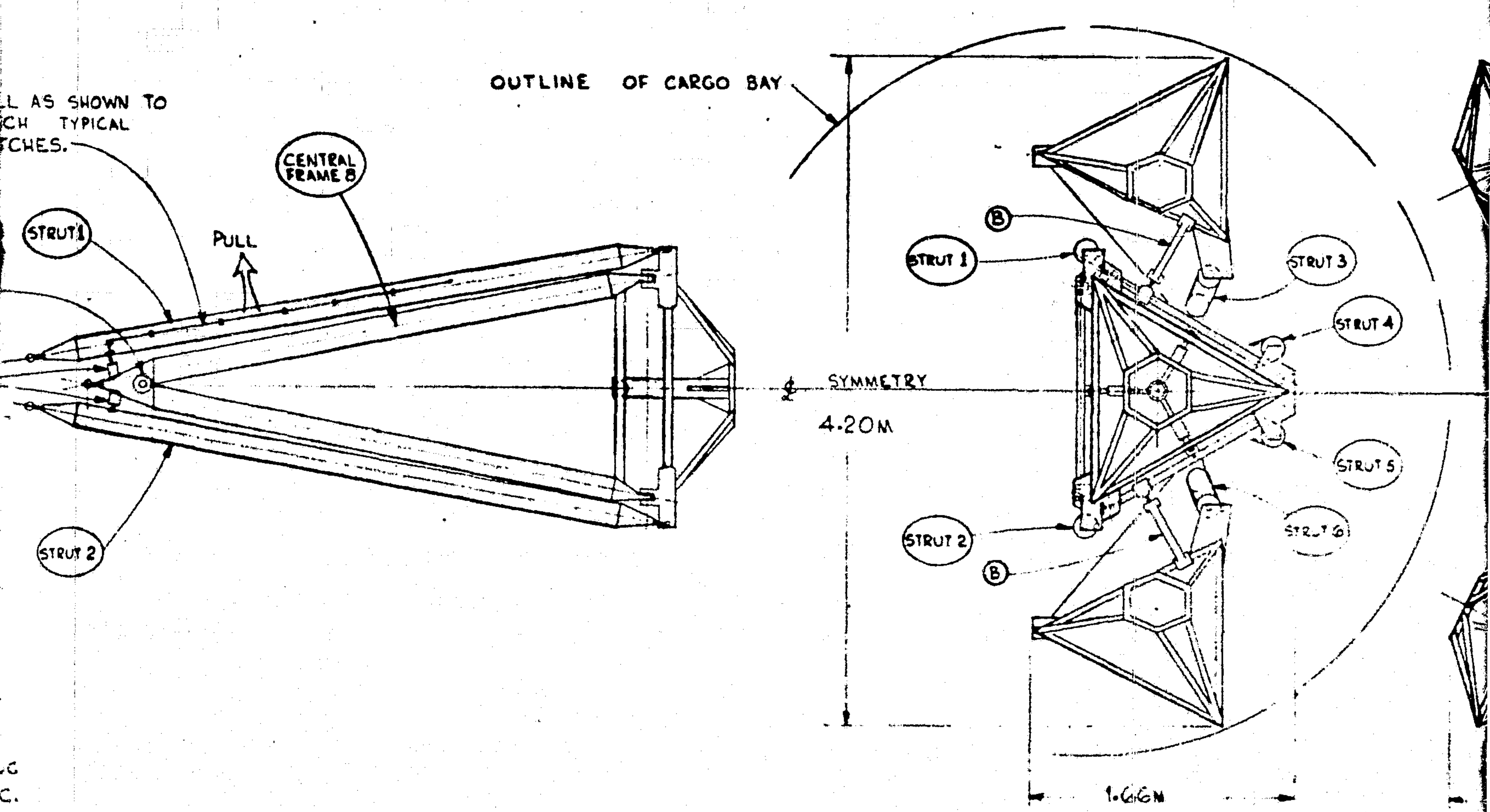
THE TWO OUTBOARD ENGINE TRUSSES ARE DEPLOYED BY THE ROTARY SPR DEVICES SHOWN IN ZONES 8A &

A

STRUTS 1 THRO 6 EQUIPPED WITH GRAS POINTS (NOT SHOWN) FOR RMS, NEAR THE FREE END OF EACH STR

FOLDOUT FRAME

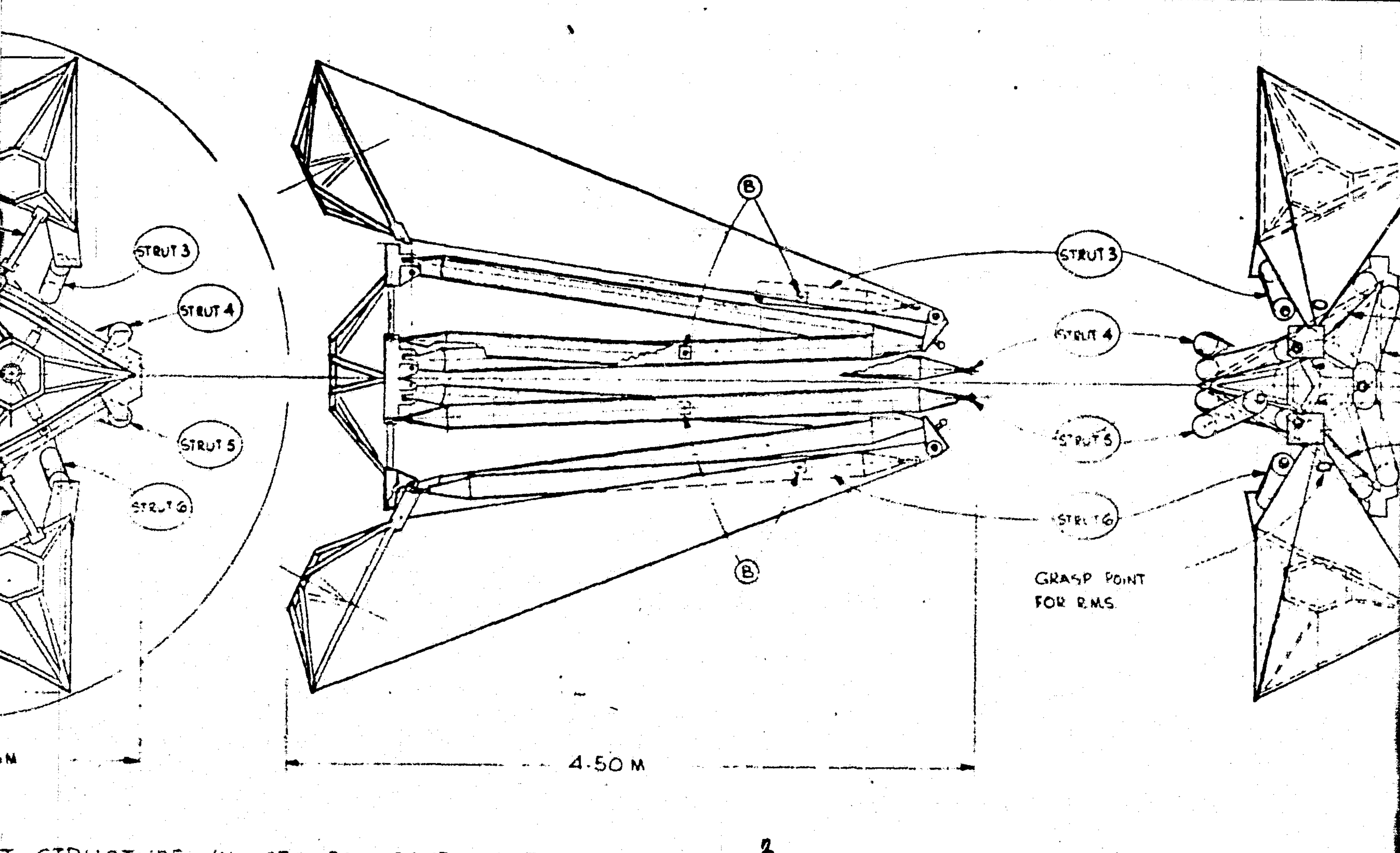
24



THRUST STRUCTURE IN STOW

SCALE : 1/20

20 | 19 | 18

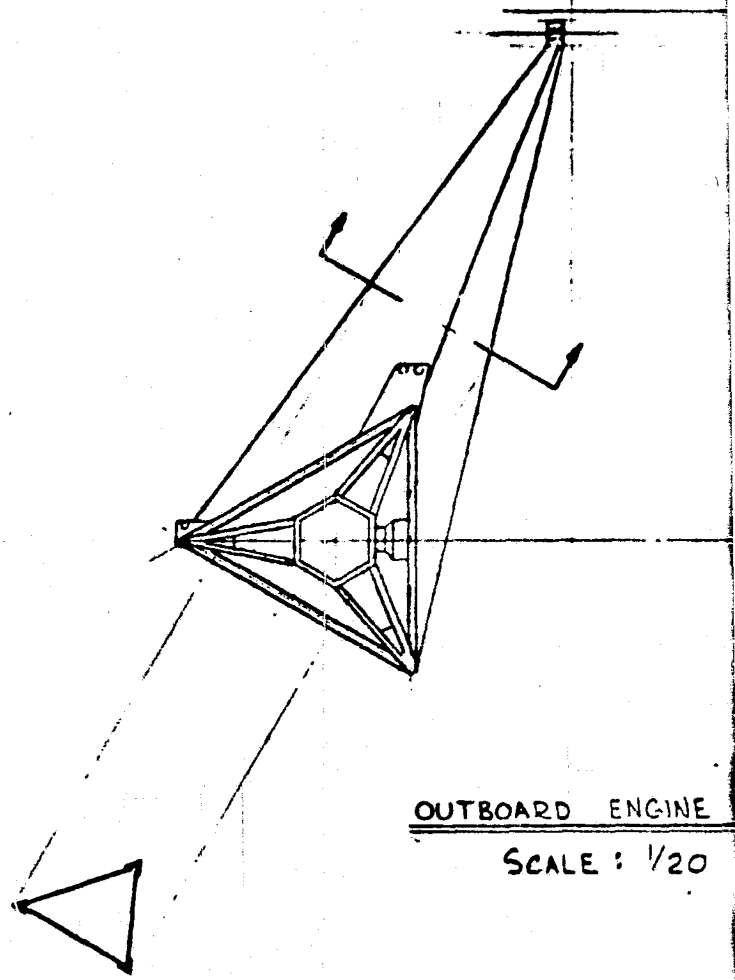


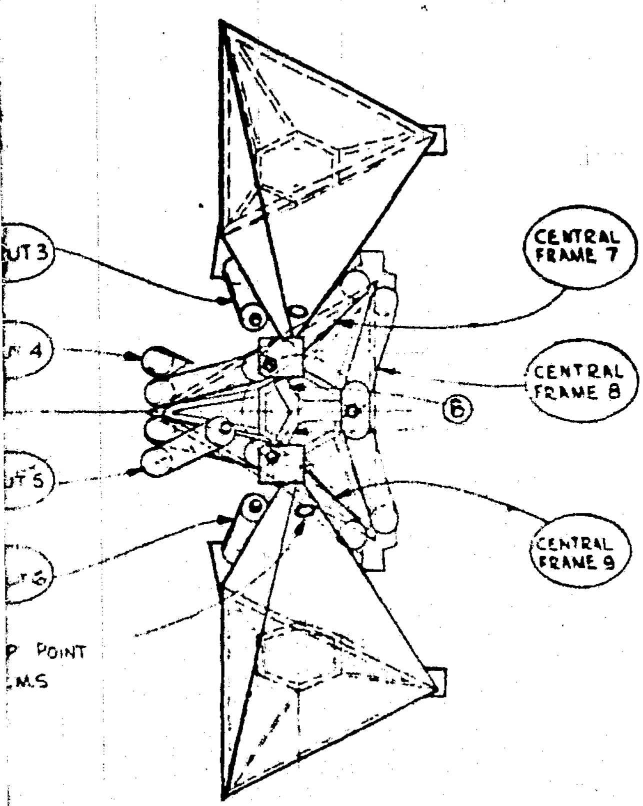
T STRUCTURE IN STOWED CONFIGURATION
SCALE : 1/20

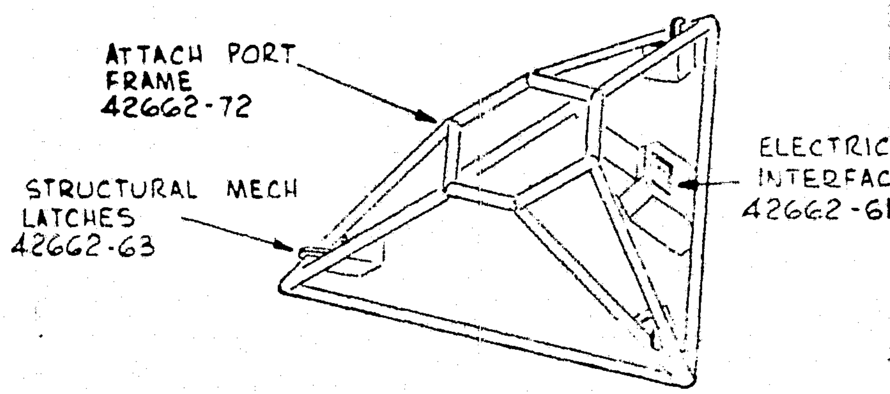
3

FOLDOUT FRAME

18 | 17 | 16 | 15





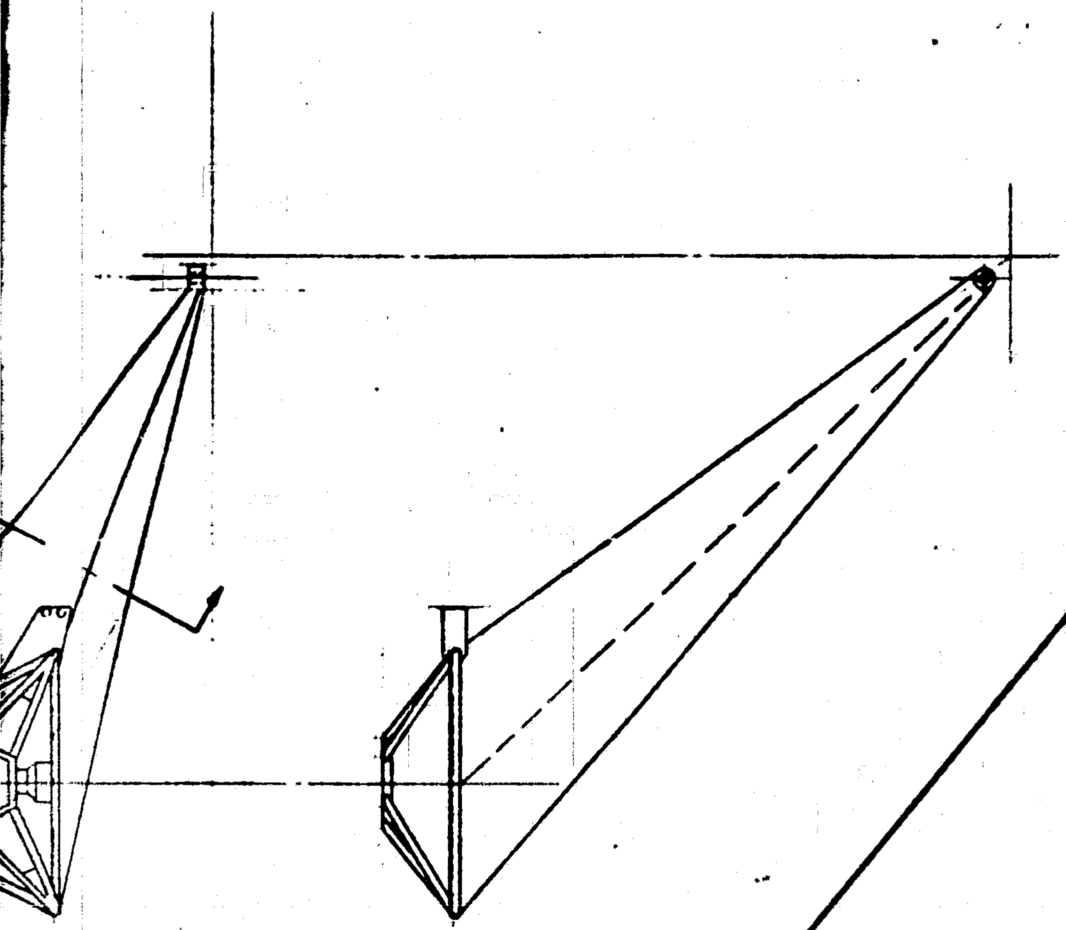


ENGINE MODULE ATTACH PORT

NO SCALE

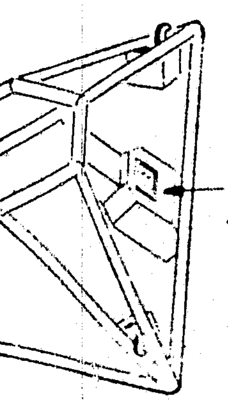
FOLDOUT FRAME

42662-60



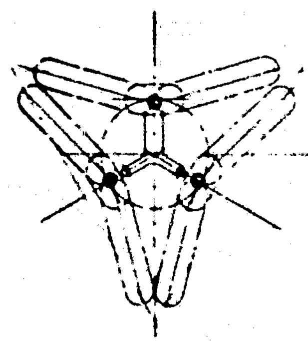
OUTBOARD ENGINE TRUSS

SCALE : 1/20



E ATTACH PORT

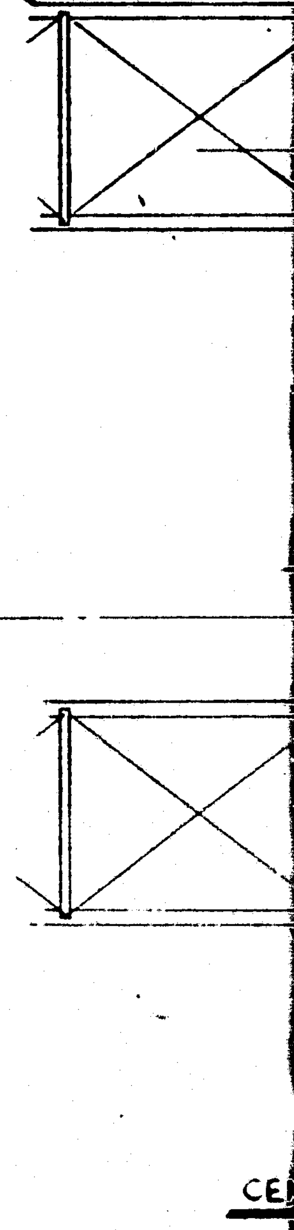
SCALE



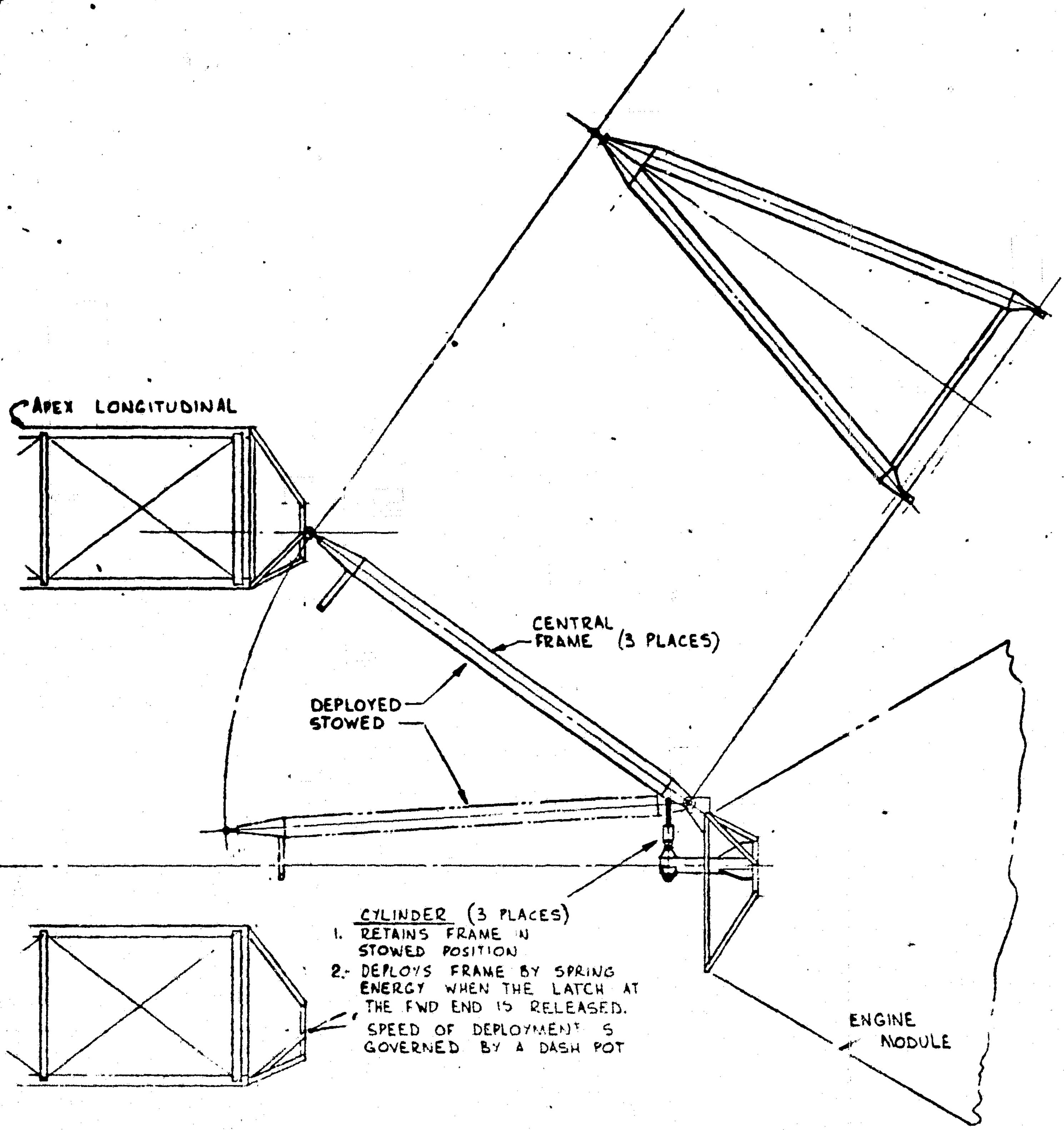
PROJECTION SHOWING THE 3 CENTRAL FRAMES N THE STOWED POSITION, JOINED TOGETHER AT THEIR FWD ENDS BY A LATCH SYSTEM. FOR DEPLOYMENT THE LATCHES ARE RELEASED INDIVIDUALLY.

5 FOLDOUT FRAME

APEX LONGITUDIN



CE



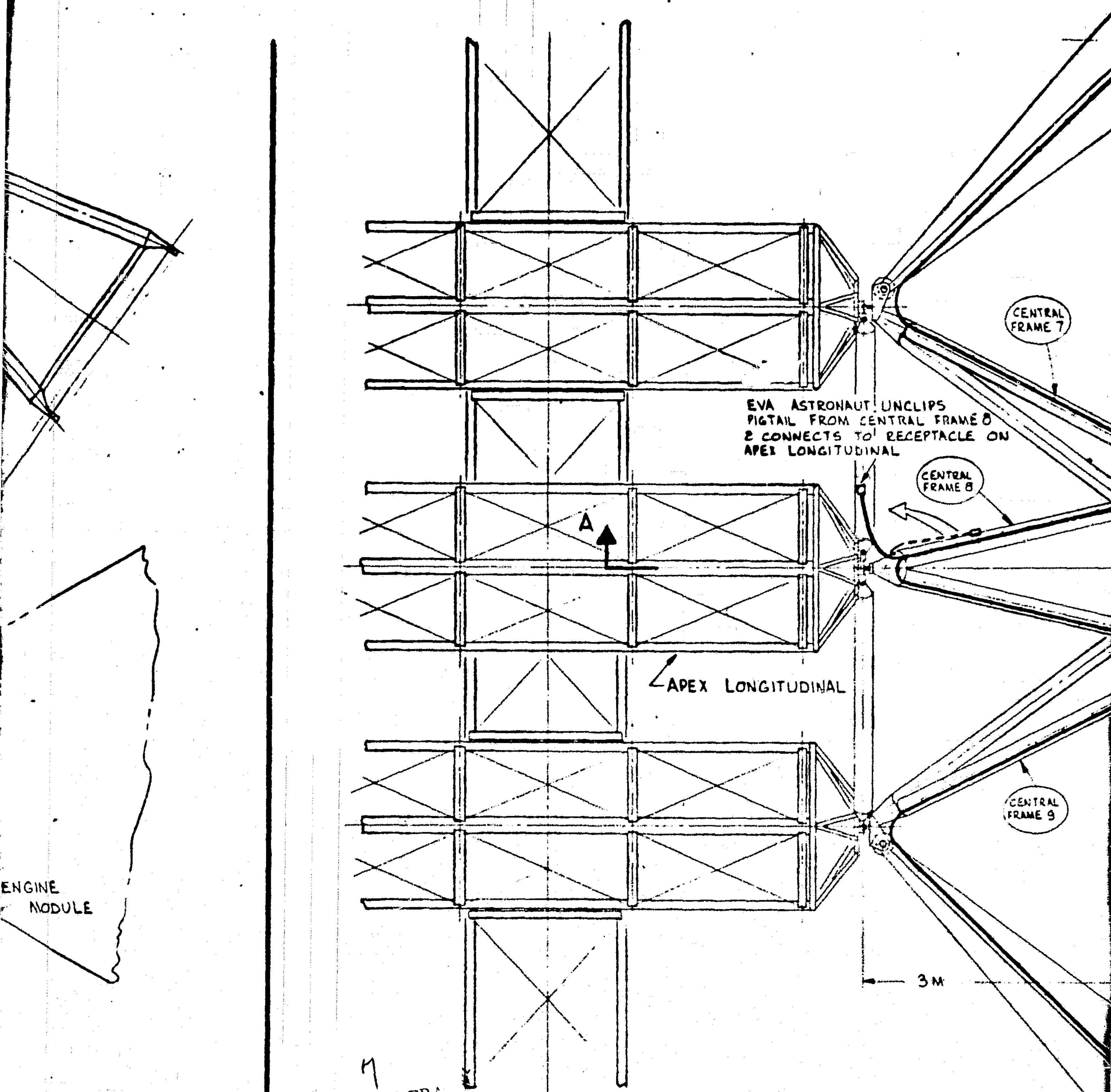
SECTION AA
CENTRAL FRAME

4

CENTER ENGINE MOUNT

FOLDOUT FRAME

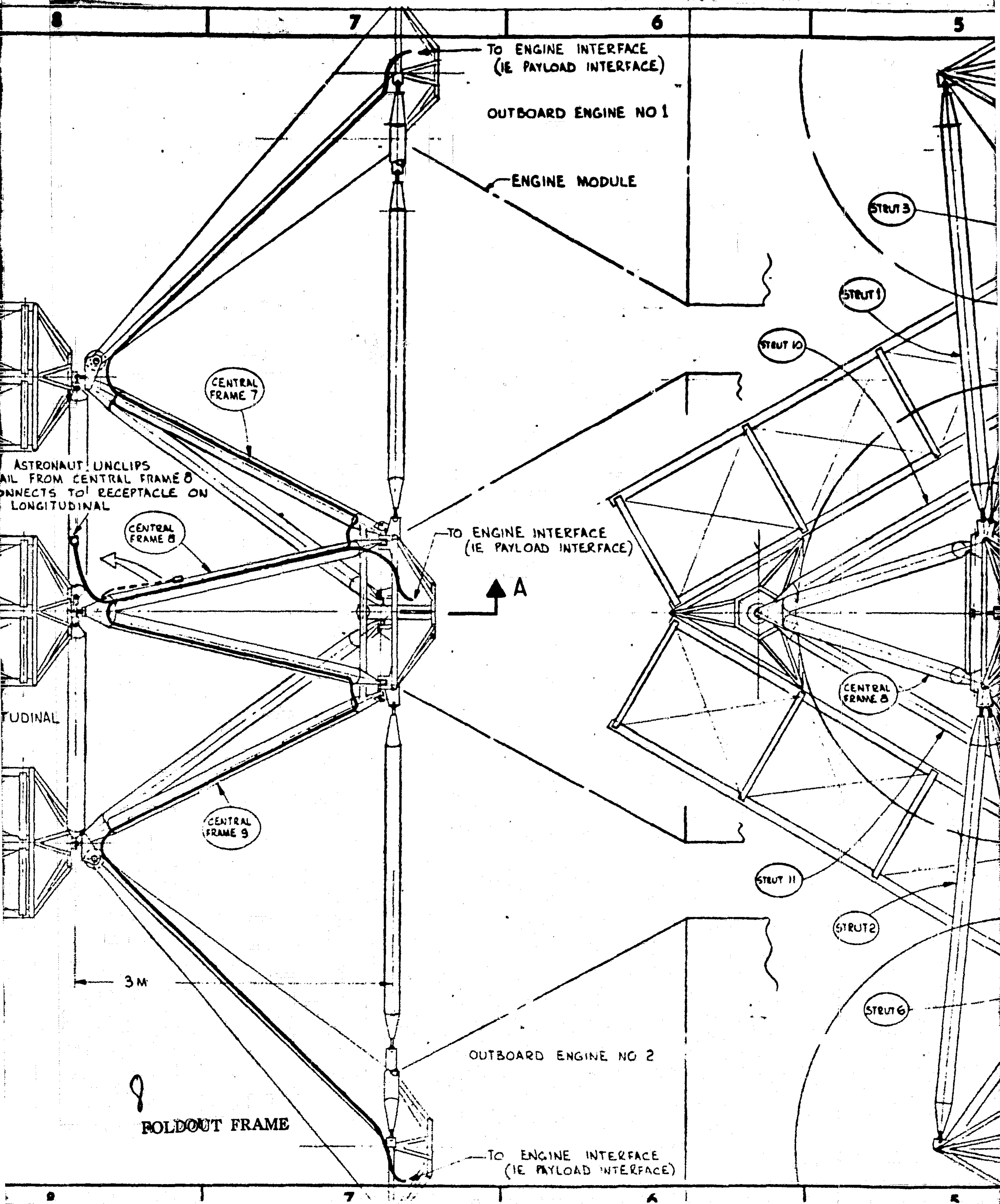
SCALE = 1/20



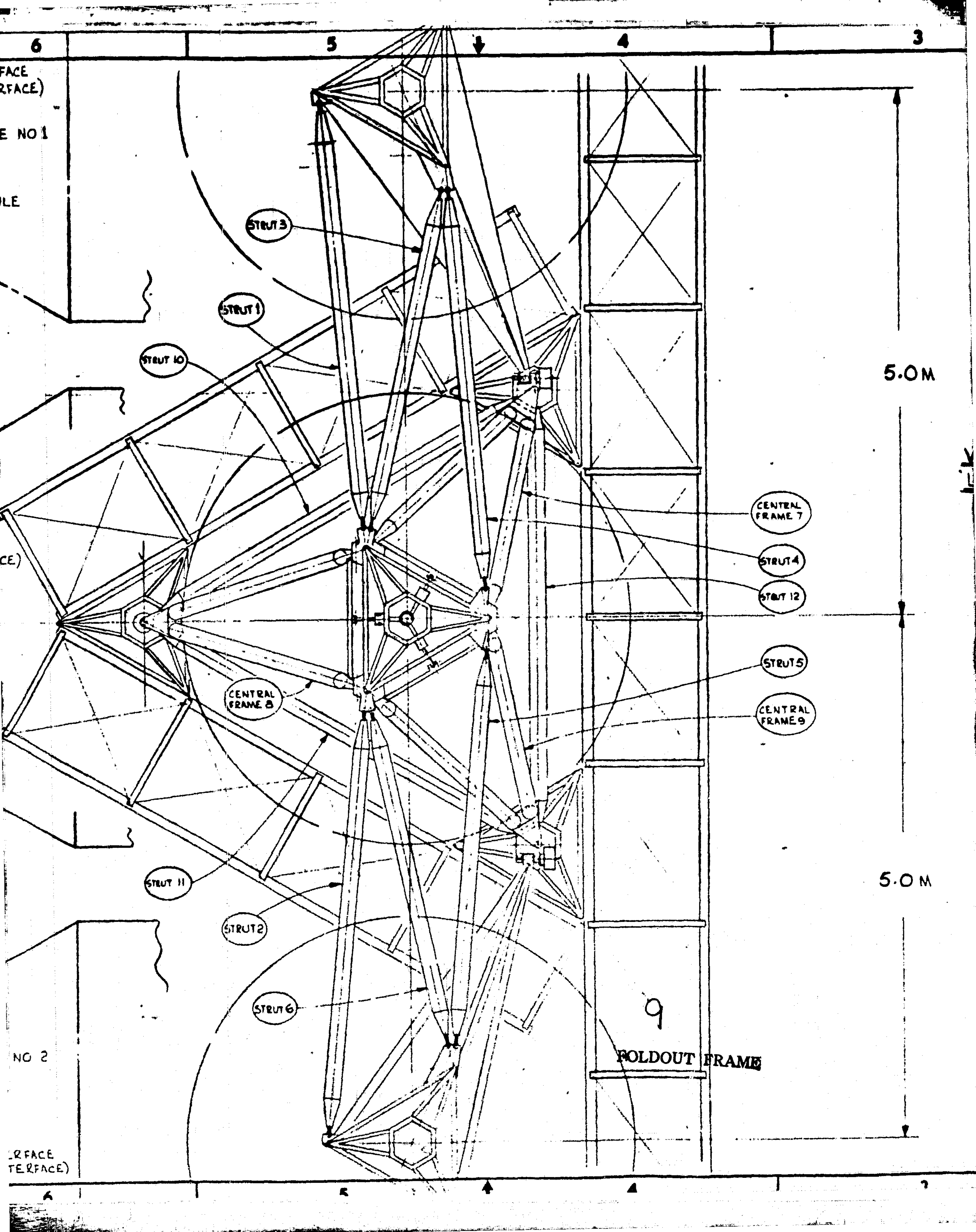
FOLDOUT FRAME

FOLDOUT FR

42662-60



FOLDOUT FRAME



9

FOLDOUT FRAME

3 | 2 | 1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

D

5.0M

VIEW FROM AFT END
LOOKING FWD
SCALE : 1/20

C

REFERENCE DWGS

42662-45 GEN ARRGT OF PLATFORM.
42662-63 STRUCTURAL/MECHANICAL LATCH FOR PAYLOAD.
42662-61 PAYLOAD INTERFACE CONNECTOR (ELECTRIC).
42662-72 MODULE ATTACH PORTS.

B

5.0M

FOLDOUT FRAME

10

A-33,
A-34

A

DR BY	R. HART	JAN 80
CHK BY		
APPROVED BY		

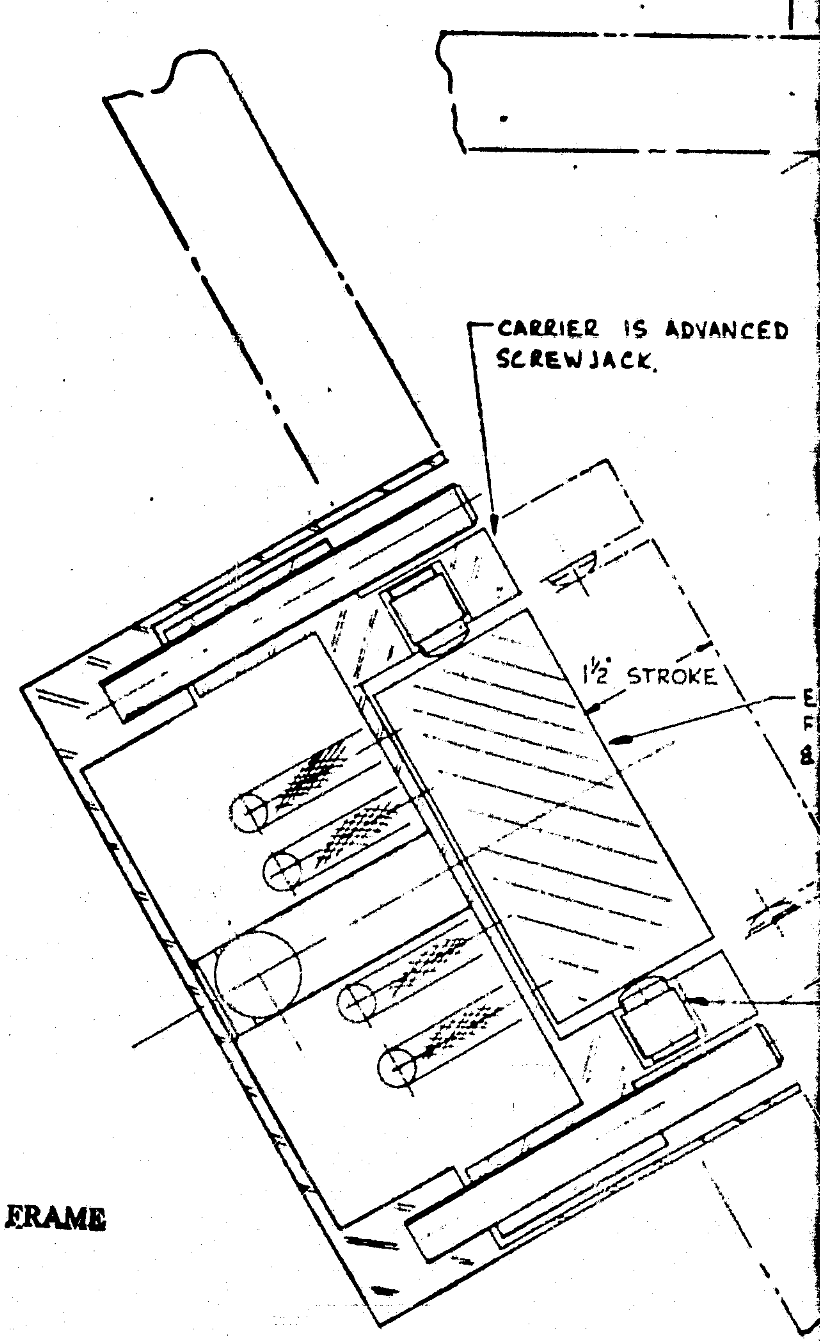
Rockwell International Corporation
Space Division
12214 Lakewood Boulevard • Downey, California 90241

INTERORBITAL THRUST STRUCTURE,
ENGINEERING TECHNOLOGY
VERIFICATION PLATFORM.

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662-60

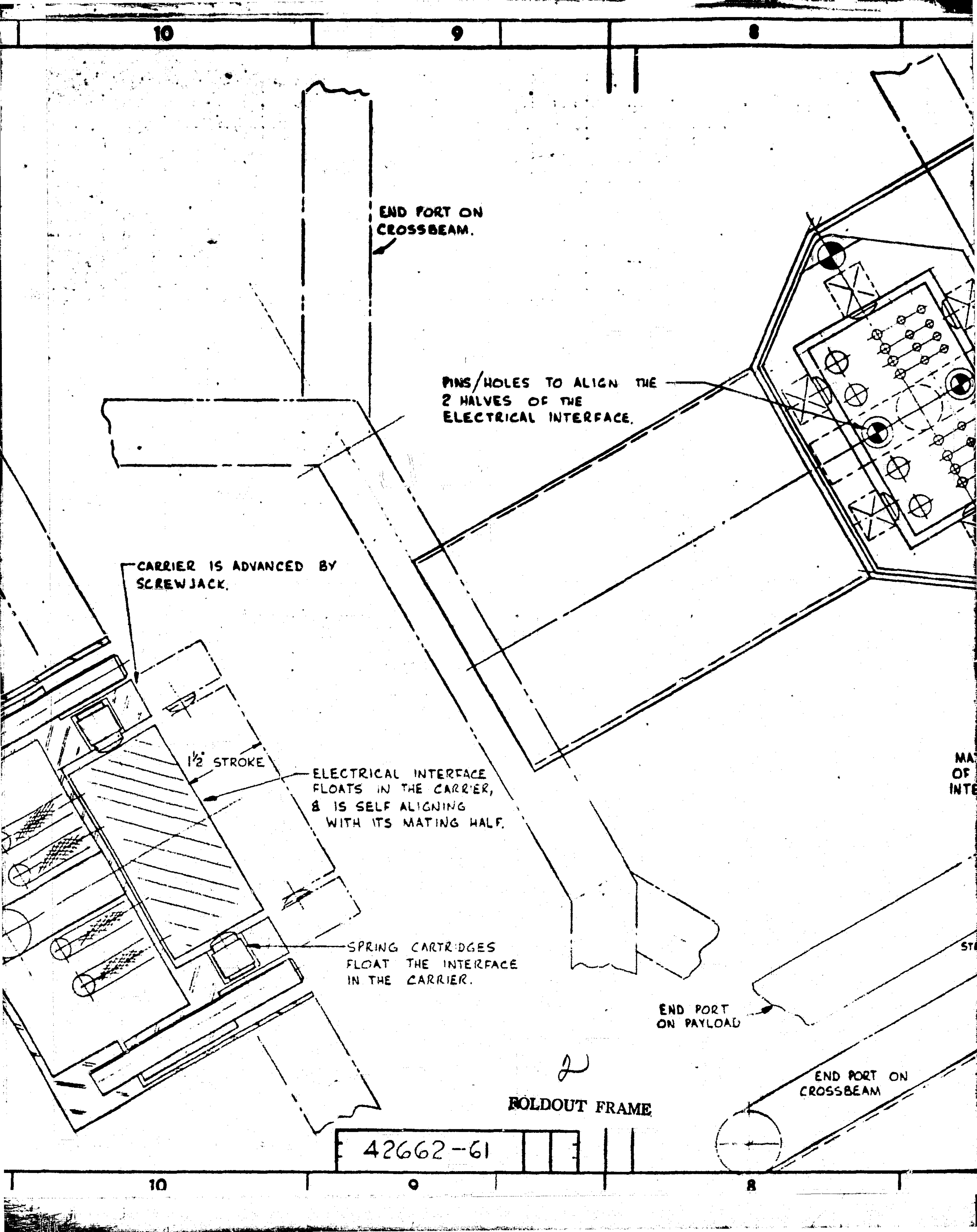
SCALE NOTED | SHEET

12	11	10



FOLDOUT FRAME

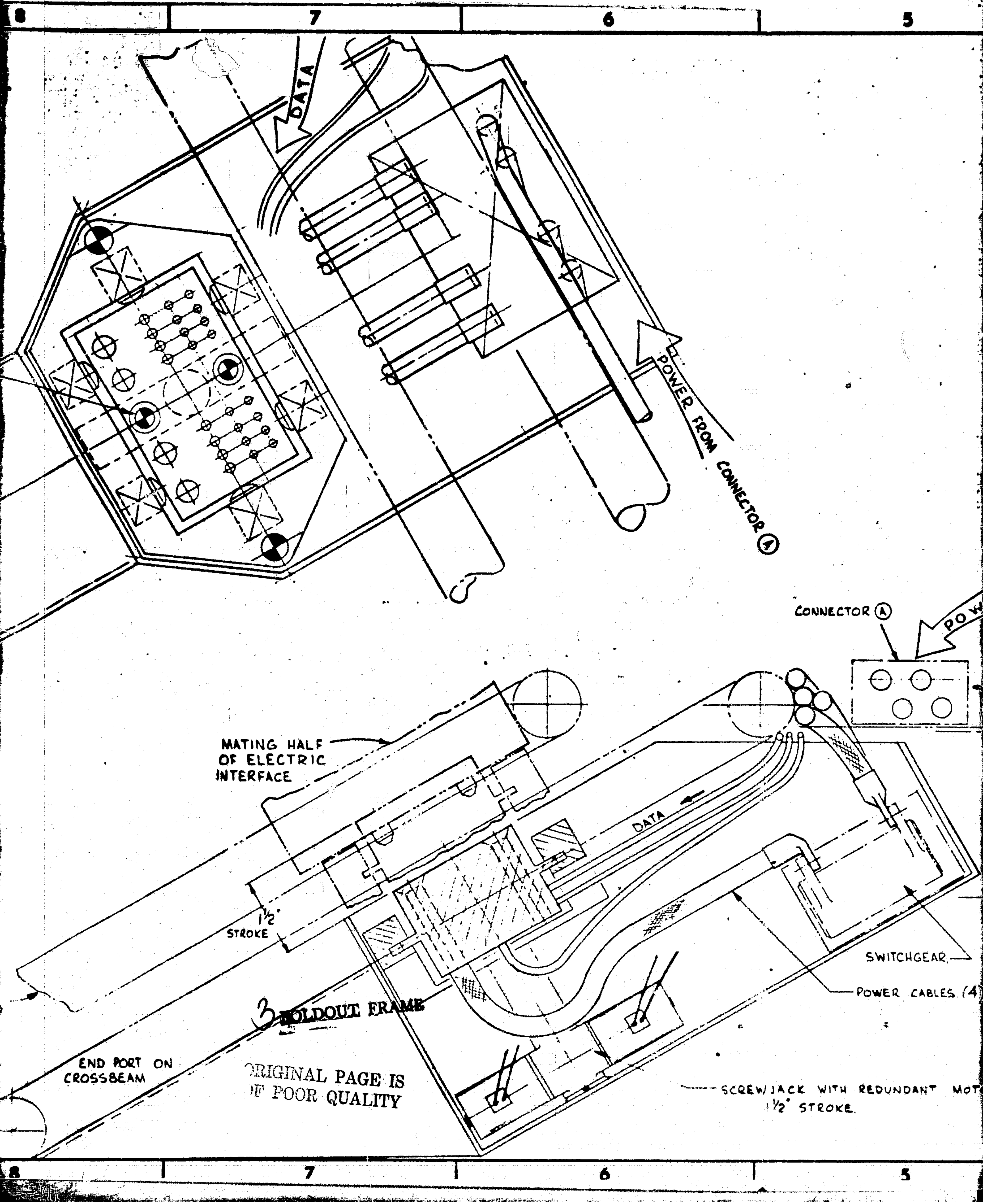
12	11	10



FOLDOUT FRAME

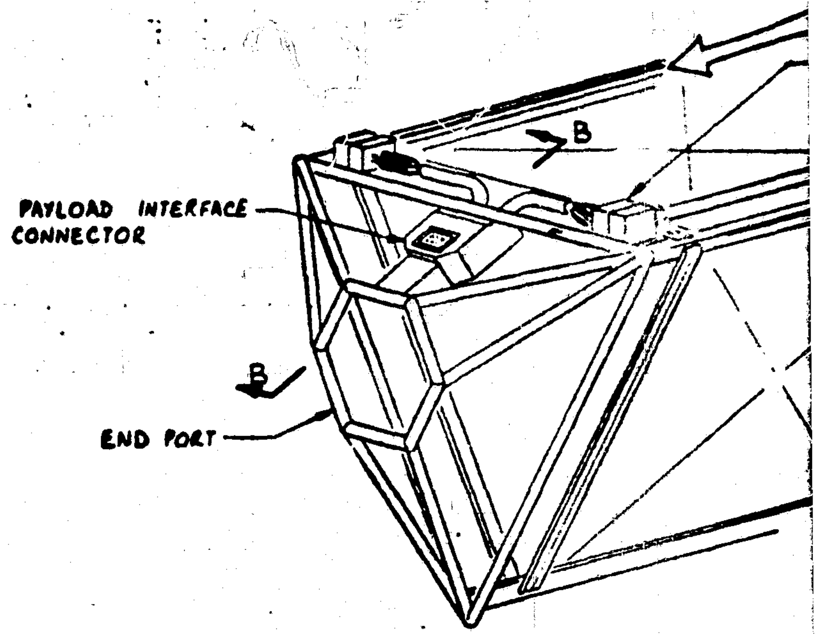
42662-61

2

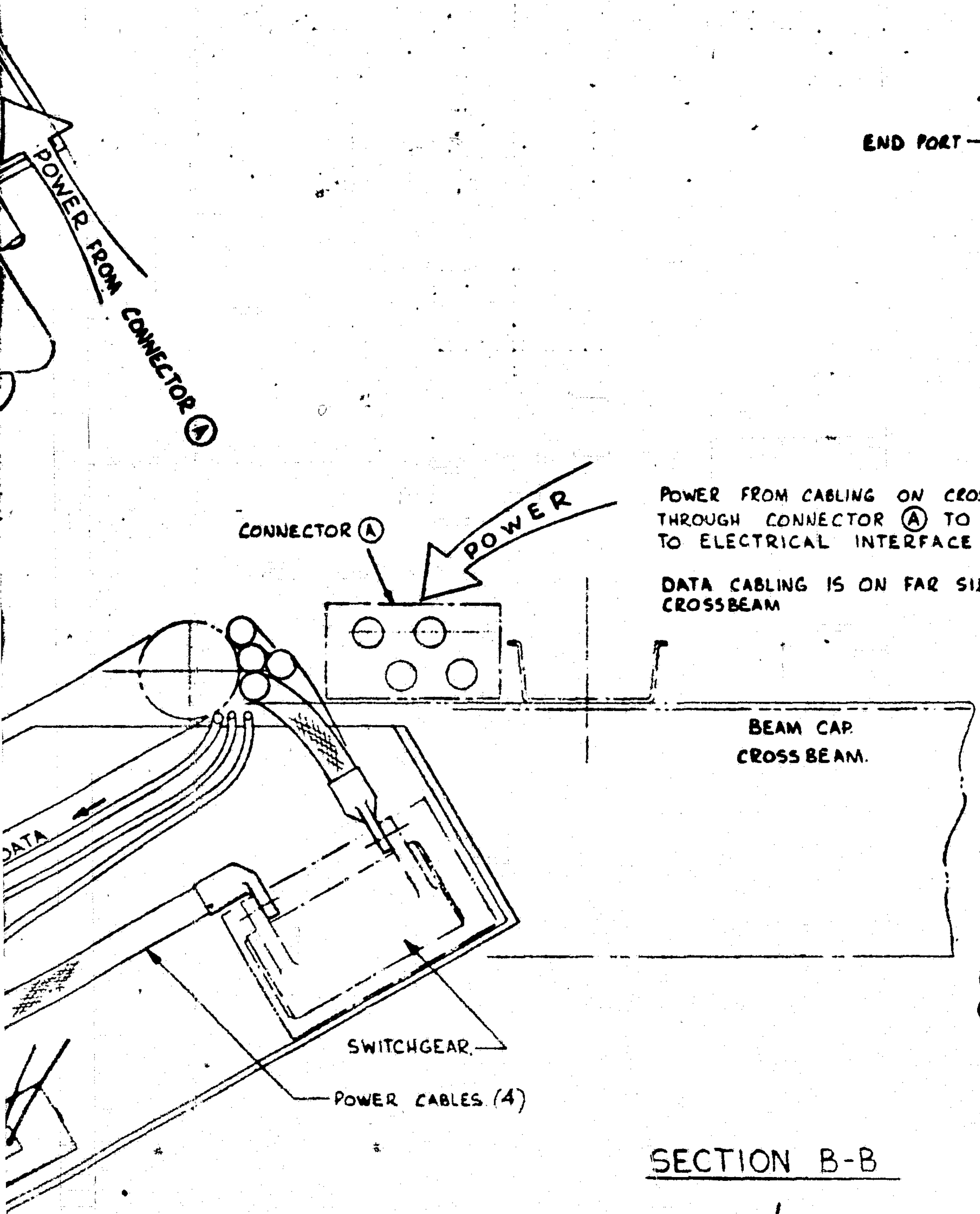


3 FOLDOUT FRAME

ORIGINAL PAGE IS
OF POOR QUALITY



VIEW SHOWING LOC
OF PAYLOAD INTER
CONNECTOR ON EN
NO SCALE



POWER FROM CABLING ON CROSSBEAM THROUGH CONNECTOR Ⓐ TO SWITCHGEAR TO ELECTRICAL INTERFACE

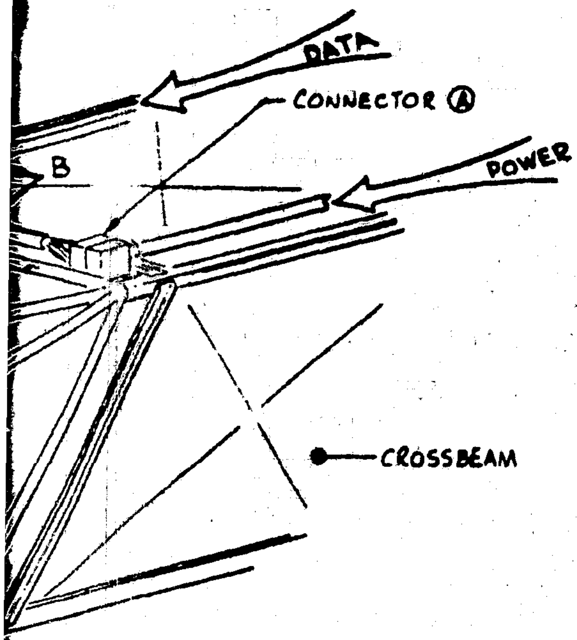
DATA CABLING IS ON FAR SIDE OF CROSSBEAM

ORIGINAL PAGE IS
OF POOR QUALITY

SECTION B-B

SCREWJACK WITH REDUNDANT MOTORS, 1½" STROKE.

4 FOLDOUT FRAME



IEW SHOWING LOCATION
F PAYLOAD INTERFACE
ONNECTOR ON END PORT
NO SCALE

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

A FUNCTIONALLY SIMILAR INTERFACE MAY BE USED FOR

BEAM BUILDER TO SUPPORT TRIPOD
SUPPORT TRIPOD TO NO I CONSTRUCTION FIXTURE. } DWG 42662-50 SHEET 4 ZONE 95

BEAM BUILDER TO Y FRAME
CABLE REEL ASSY FRAME TO Y FRAME
ORBITER TO Y FRAME } DWG 42662-52 SHEET 2 ZONE 8

5 FOLDOUT FRAME

A-35,
A-36

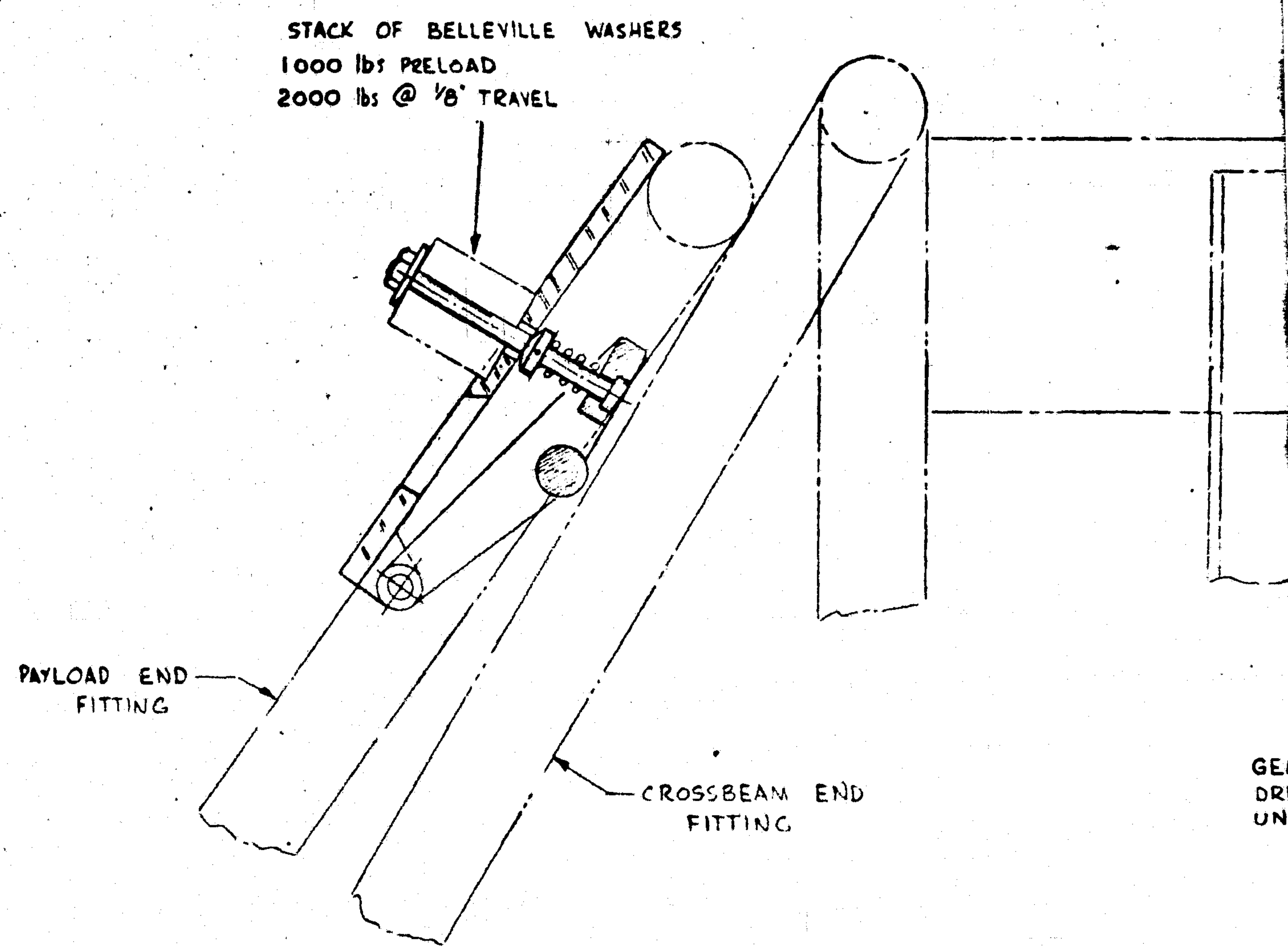
DR BY	R. HART	
CHK BY		
APPROVED BY		

Rockwell International Corporation
Space Division
12214 Lakewood Boulevard • Downey, California 90241

PAYLOAD INTERFACE CONNECTOR (ELECTRIC) E.T.V.P.

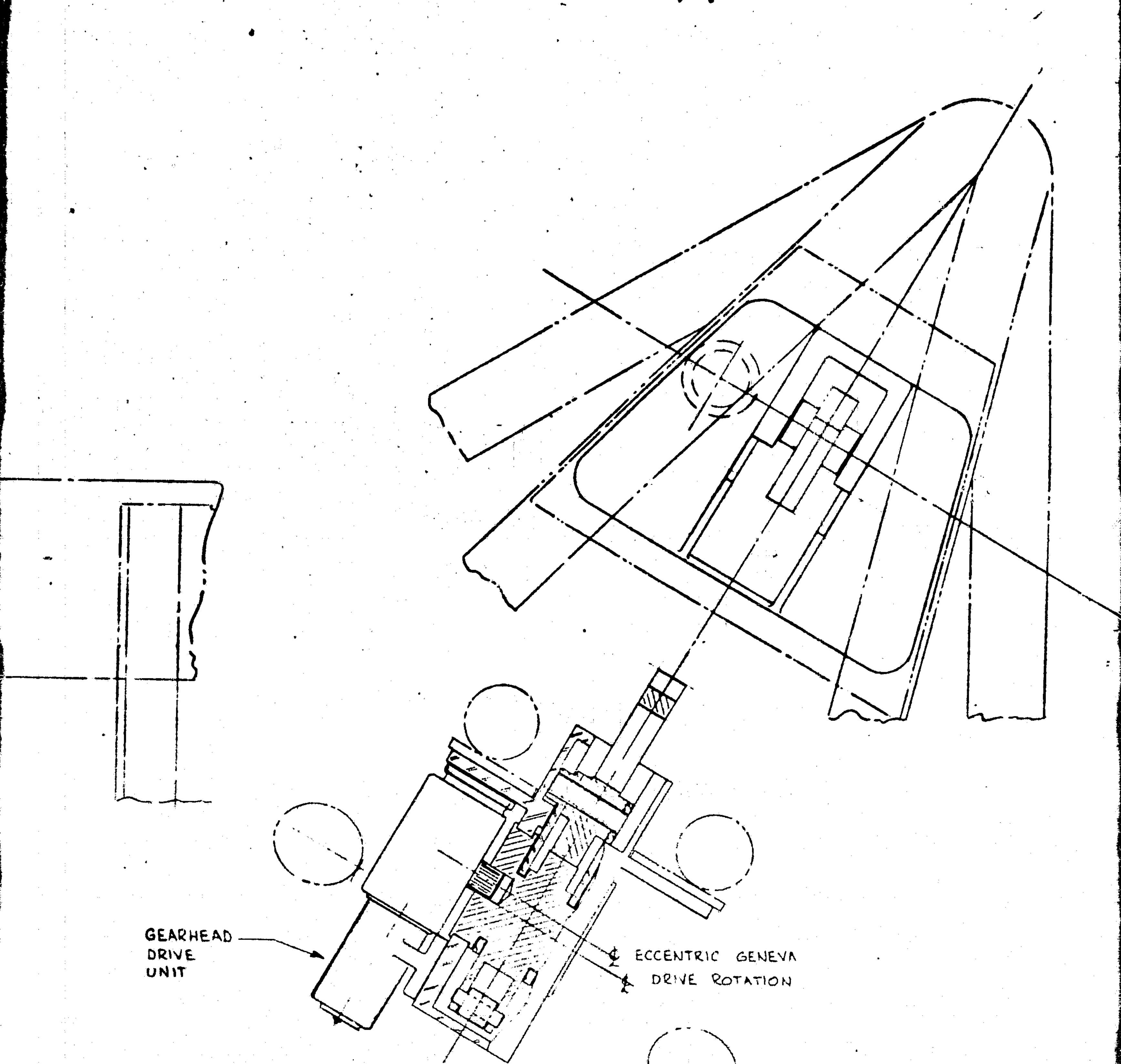
SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662-61

SCALE | SHEET



PAYLOAD SIDE OF INTERFACE

FOLDOUT FRAME

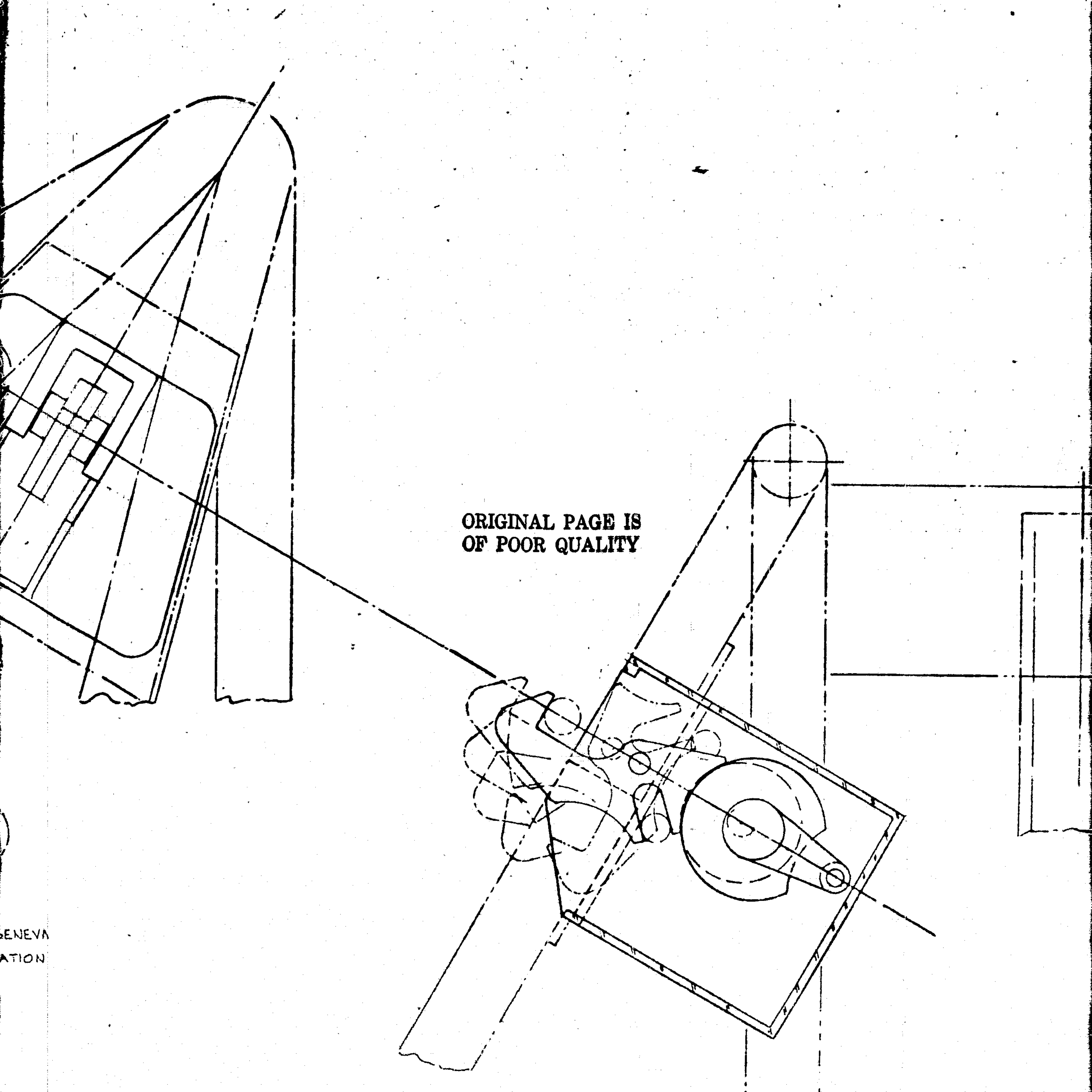


ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME

CROSSBEAM SIDE OF
INTERFACE

42662-63



ORIGINAL PAGE IS
OF POOR QUALITY

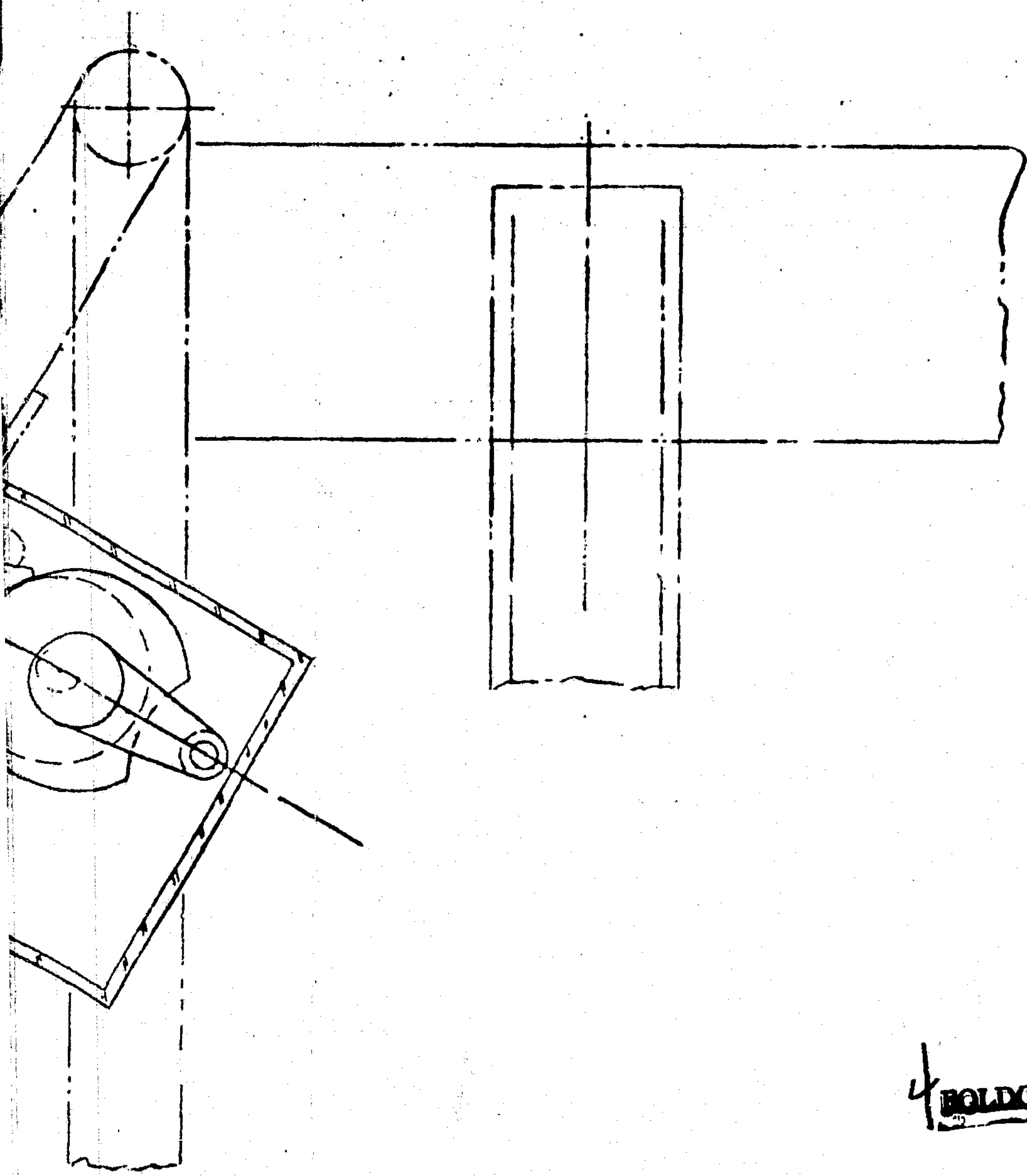
CROSSBEAM SIDE OF
INTERFACE

3 FOLDOUT FRAME

A FUNCTIONALLY SIMILAR LATCH

BEAM BUILDER TO SUPPO
SUPPORT TRIPOD TO NO 1

BEAM BUILDER TO Y F
CABLE REEL ASSY FRAME TO



FOLDOUT FRAME

3 2 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

D

LATCH IS USED FOR
SUPPORT TRIPOD
TO NO 1 CONSTRUCTION FIXTURE } DWG 42662-50 SHEET 4 ZONE 5B

TO Y FRAME
RAME TO Y FRAME } DWG 42662-52 SHEET 2 ZONE 8

C

B

5 FOLDOUT FRAME

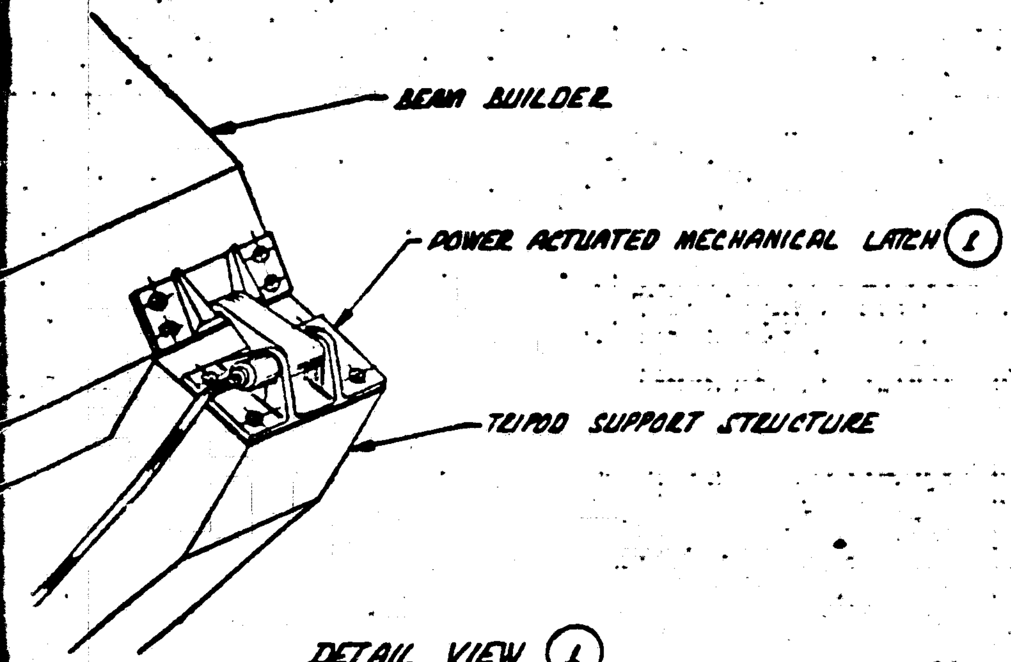
A-37,
A-38

A

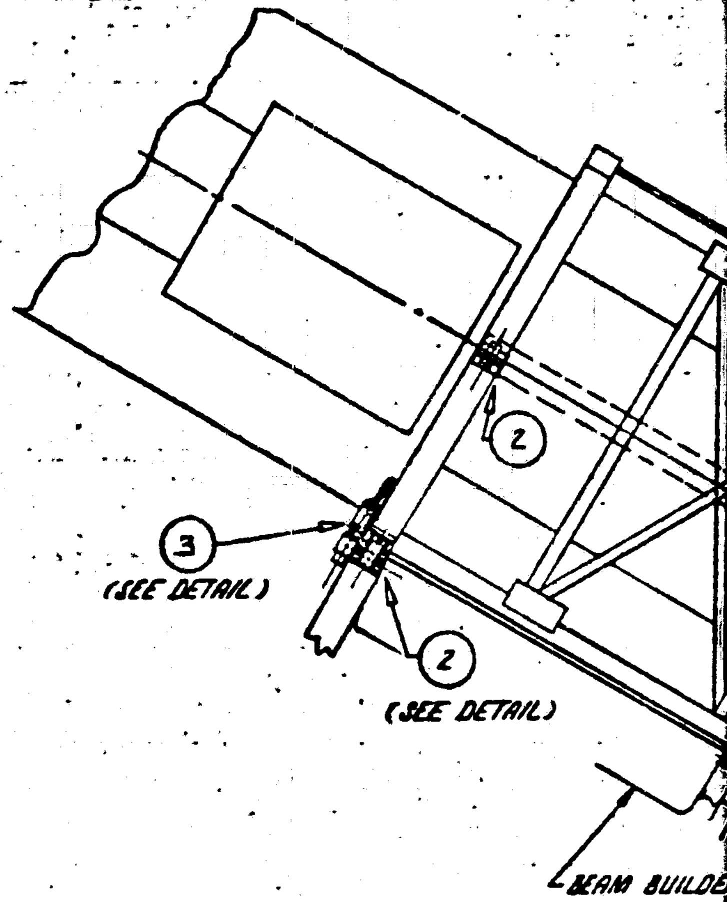
DR BY R J HART DEC 79	Rockwell International Corporation Space Division 12214 Lakewood Boulevard • Downey, California 90241
CHK BY	STRUCTURAL MECHANICAL LATCH FOR PAYLOAD ETVP
APPROVED BY	SIZE L · CODE IDENT NO 03953 · DRAWING NO. 42662-63
	SCALE FULL · SHEET

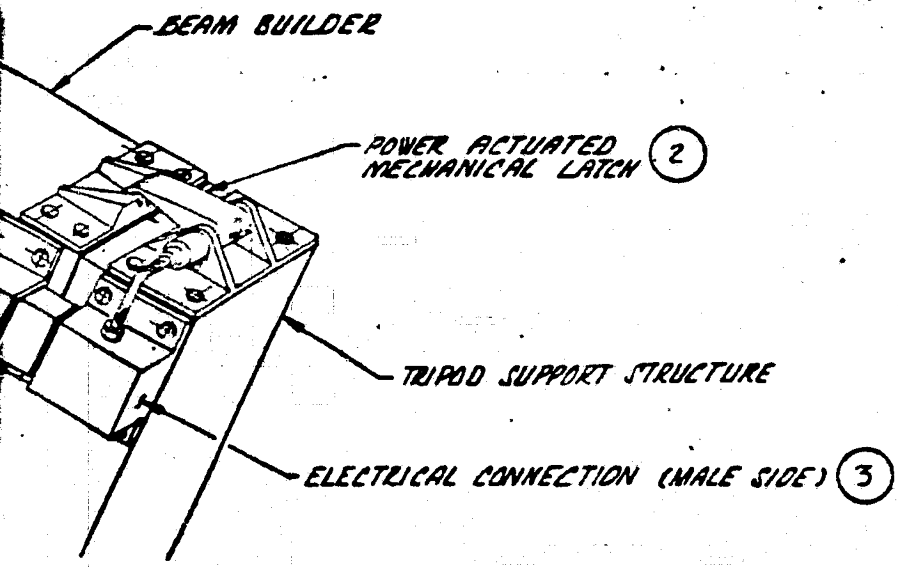
3 2 1

12 11 10



DETAIL VIEW 1





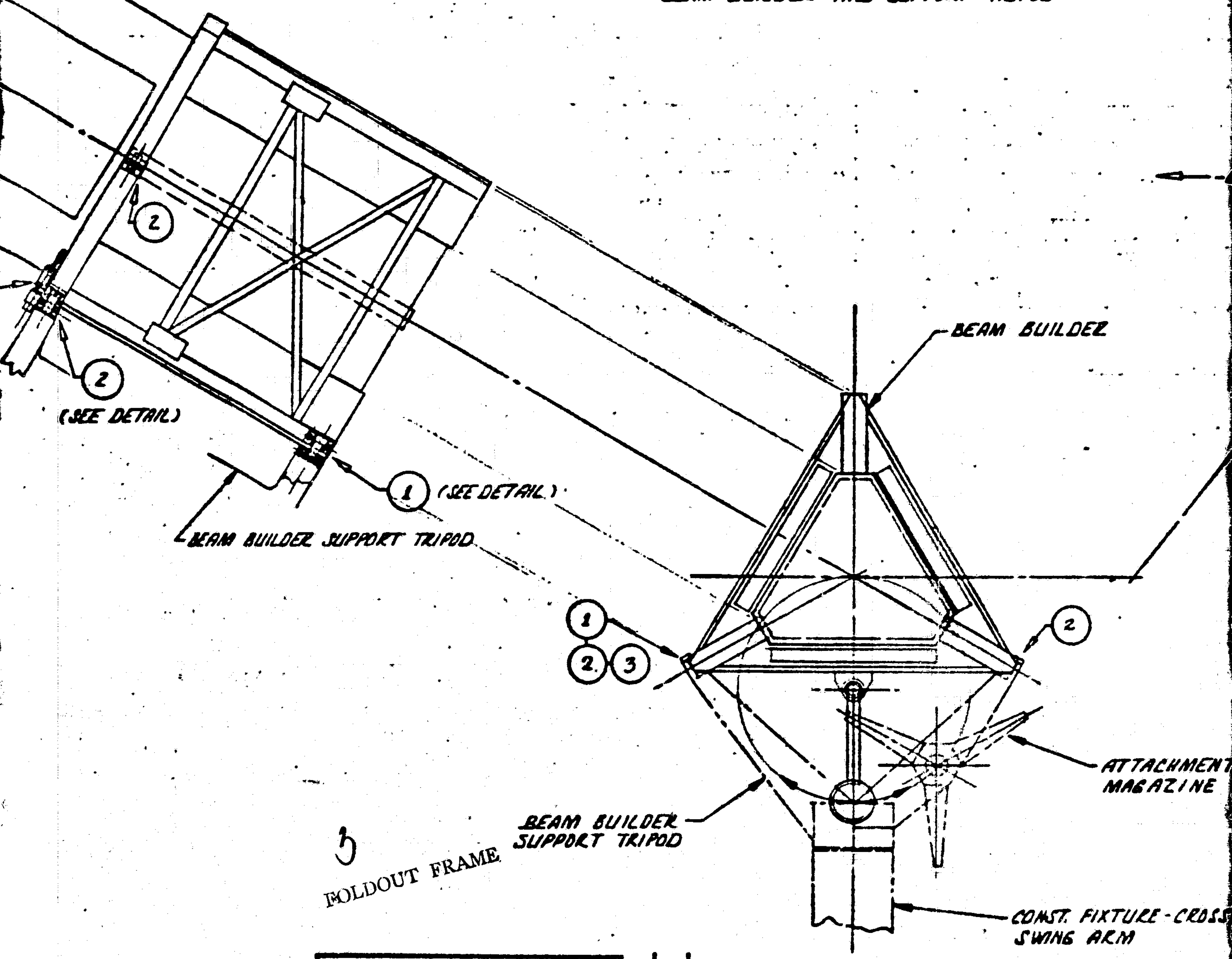
DETAIL VIEWS 2 & 3

2

FOLDOUT FRAME

SYMBOL IDENTIFICATION

1. MECHANICAL LATCH & ALIGNMENT BETWEEN BEAM BUILDER AND SUPPORT TRIPOD (FOWARD)
2. MECHANICAL LATCH & ALIGNMENT BETWEEN BEAM BUILDER AND SUPPORT TRIPOD (AFT)
3. ELECTRICAL INTERFACE CONNECTION BETWEEN BEAM BUILDER AND SUPPORT TRIPOD



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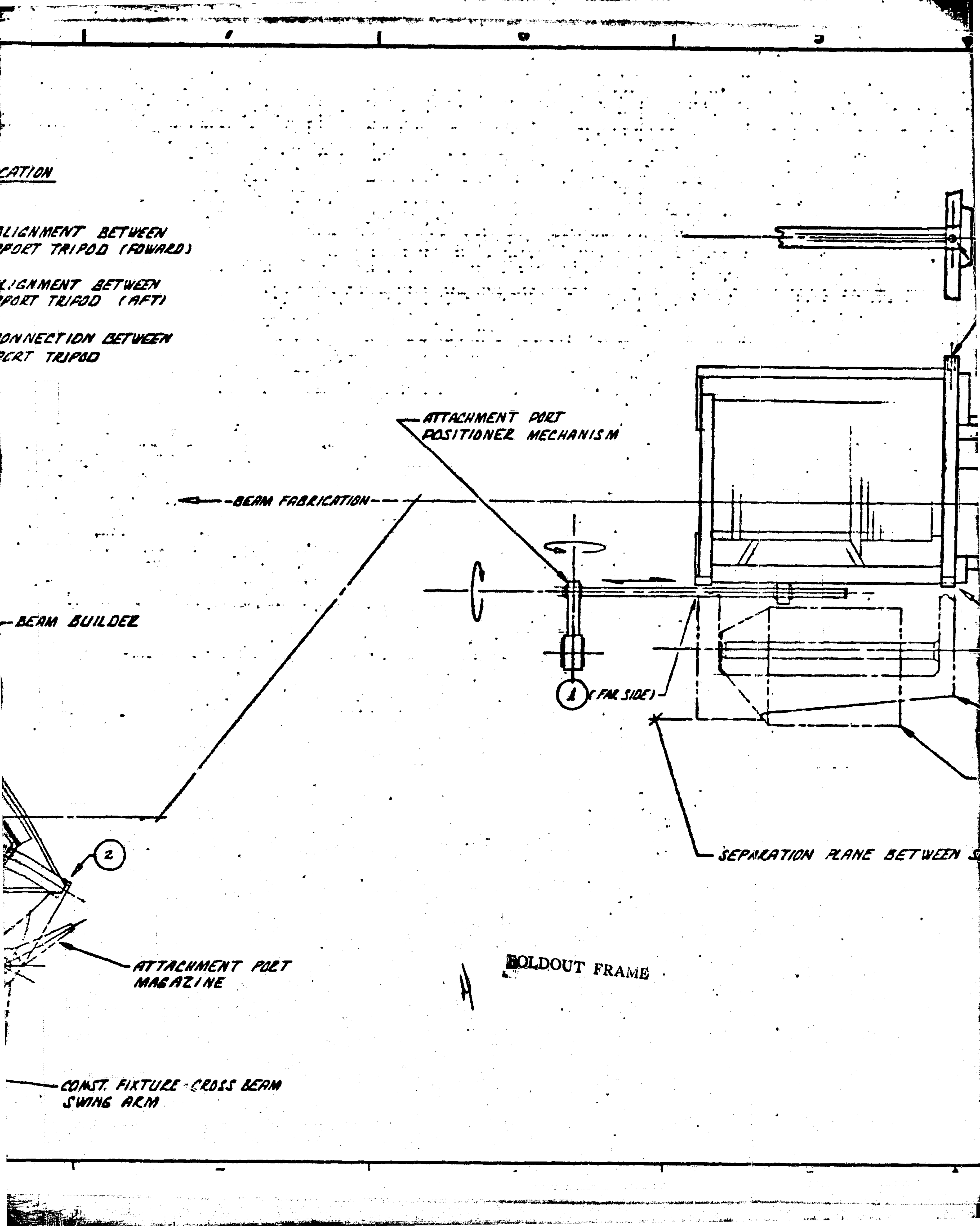
42662-64



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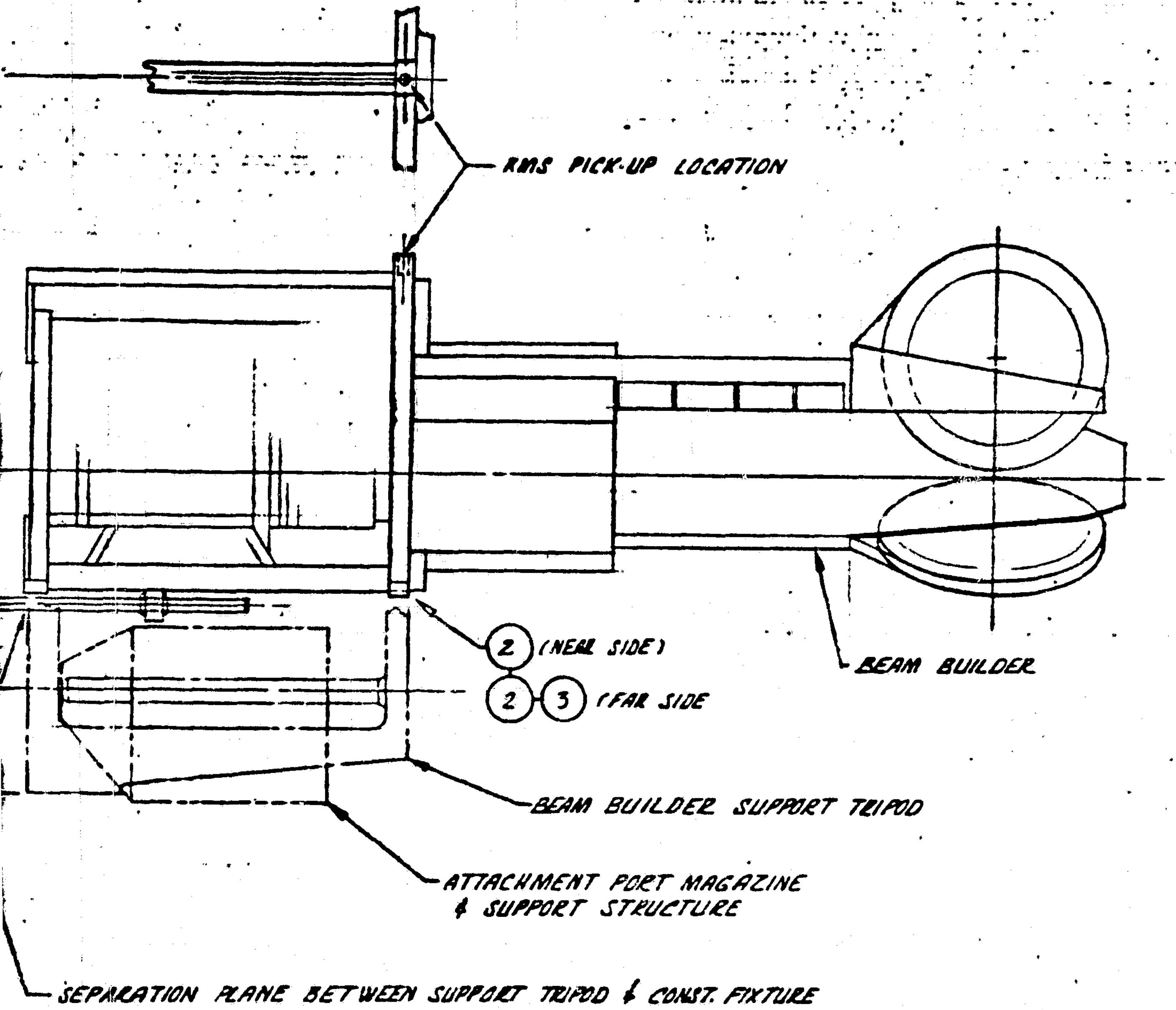

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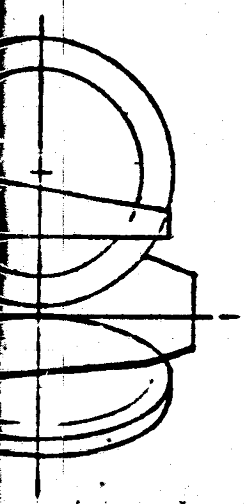
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



ILDER

FOLDOUT FRAME

A-39,
A-40

42662-64

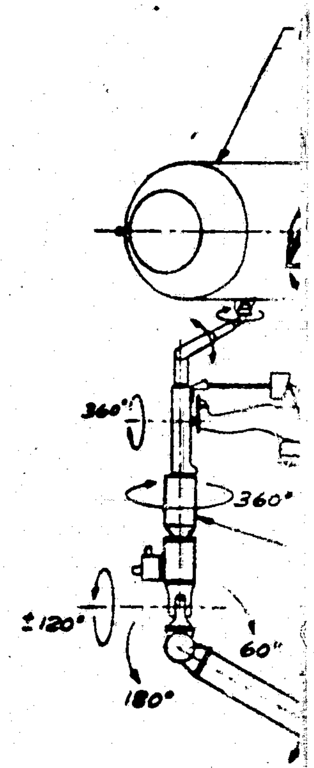
DR BY	
CHK BY	
APPROVED BY	

Rockwell International Corporation
Space Division
12214 Lakewood Boulevard · Downey, California 90241

MODIFICATION TO BEAM BUILDER - ETVP

SIZE	CODE IDENT NO.	DRAWING NO.
L	03953	42662-64

SCALE | SHEET



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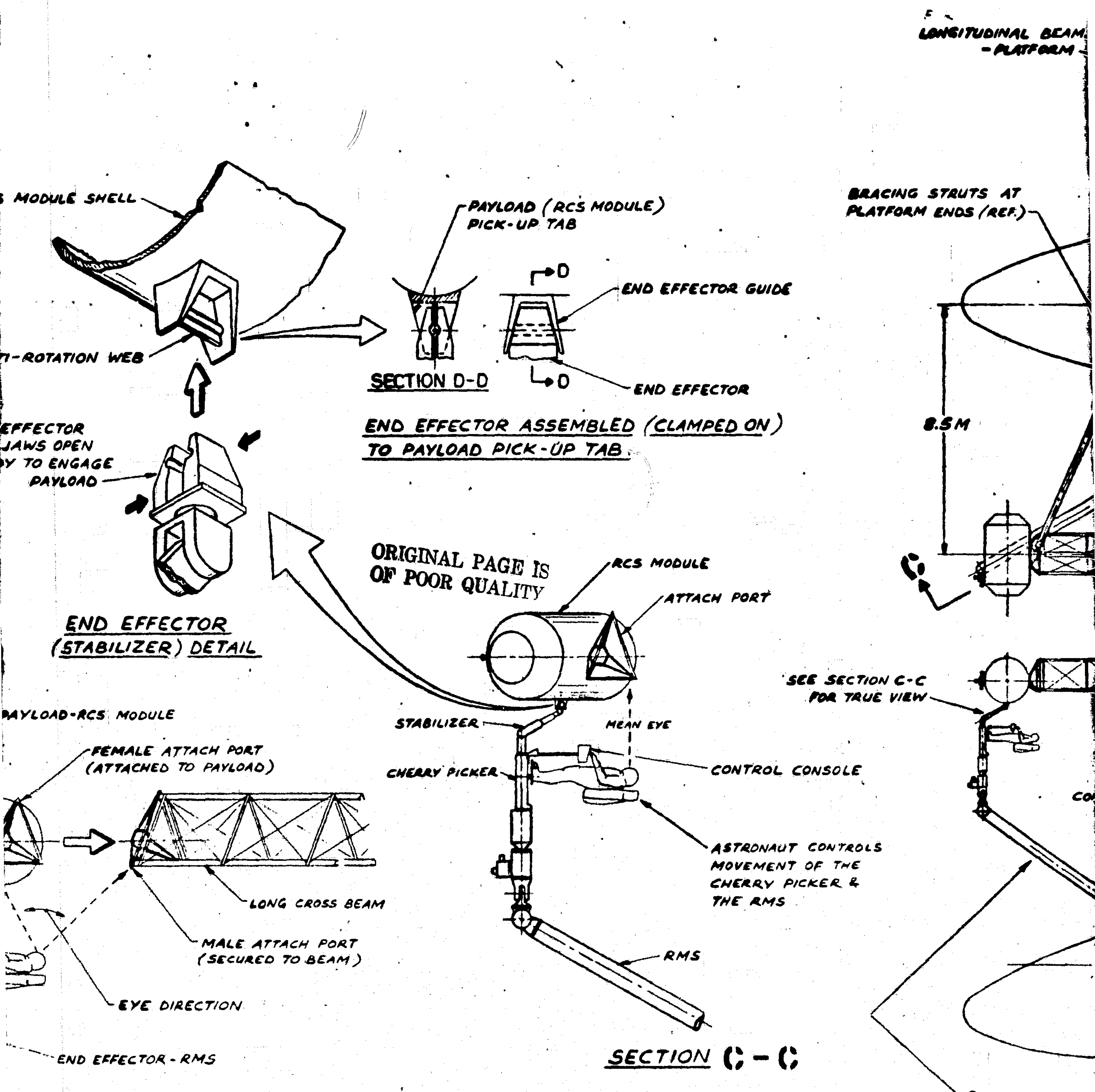
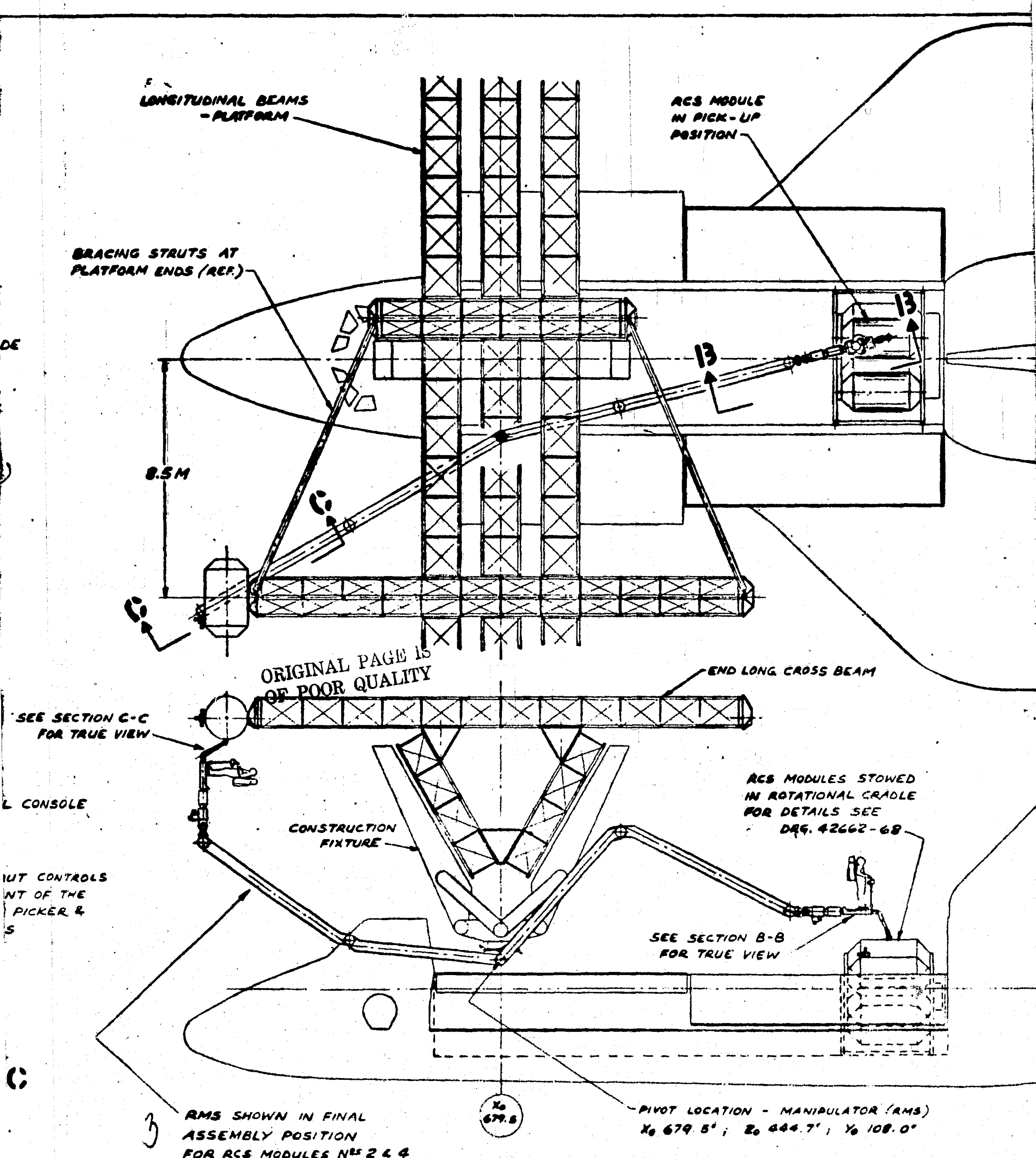


RCS MODULE ASSEMBLY

SCALE : 1/40

FOLDOUT FRAME



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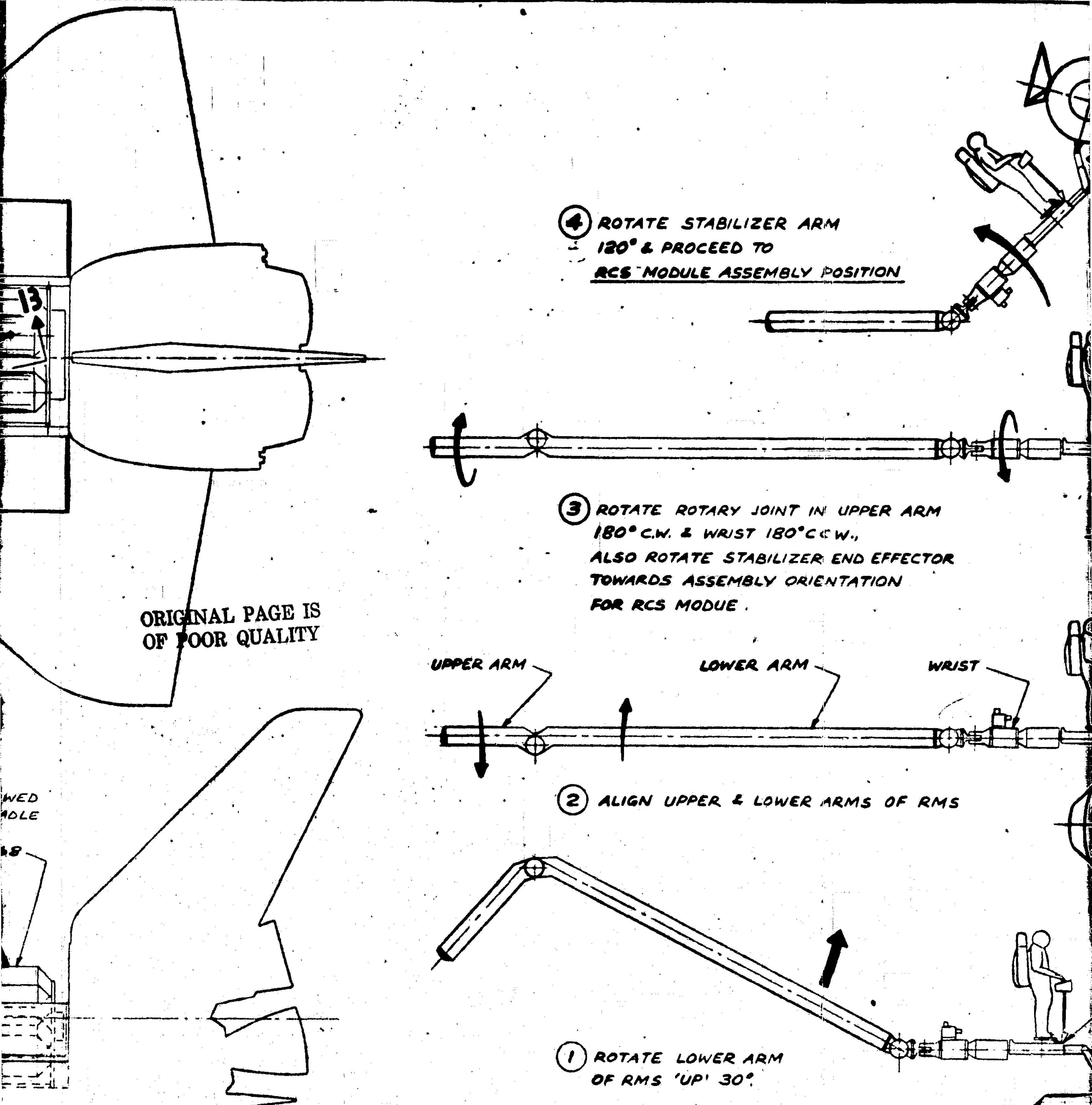
SECTION A - A

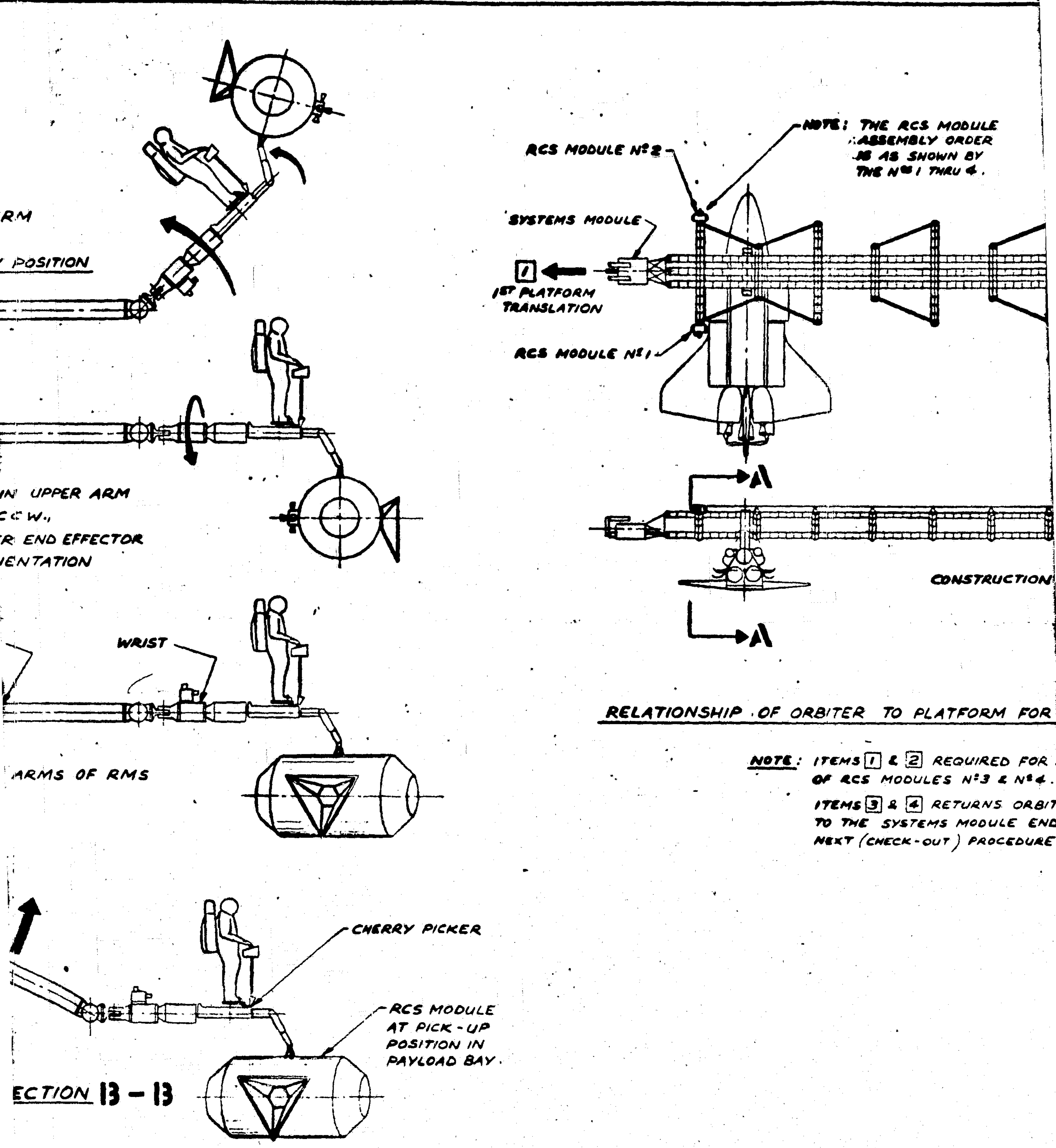
SCALE : 1/80



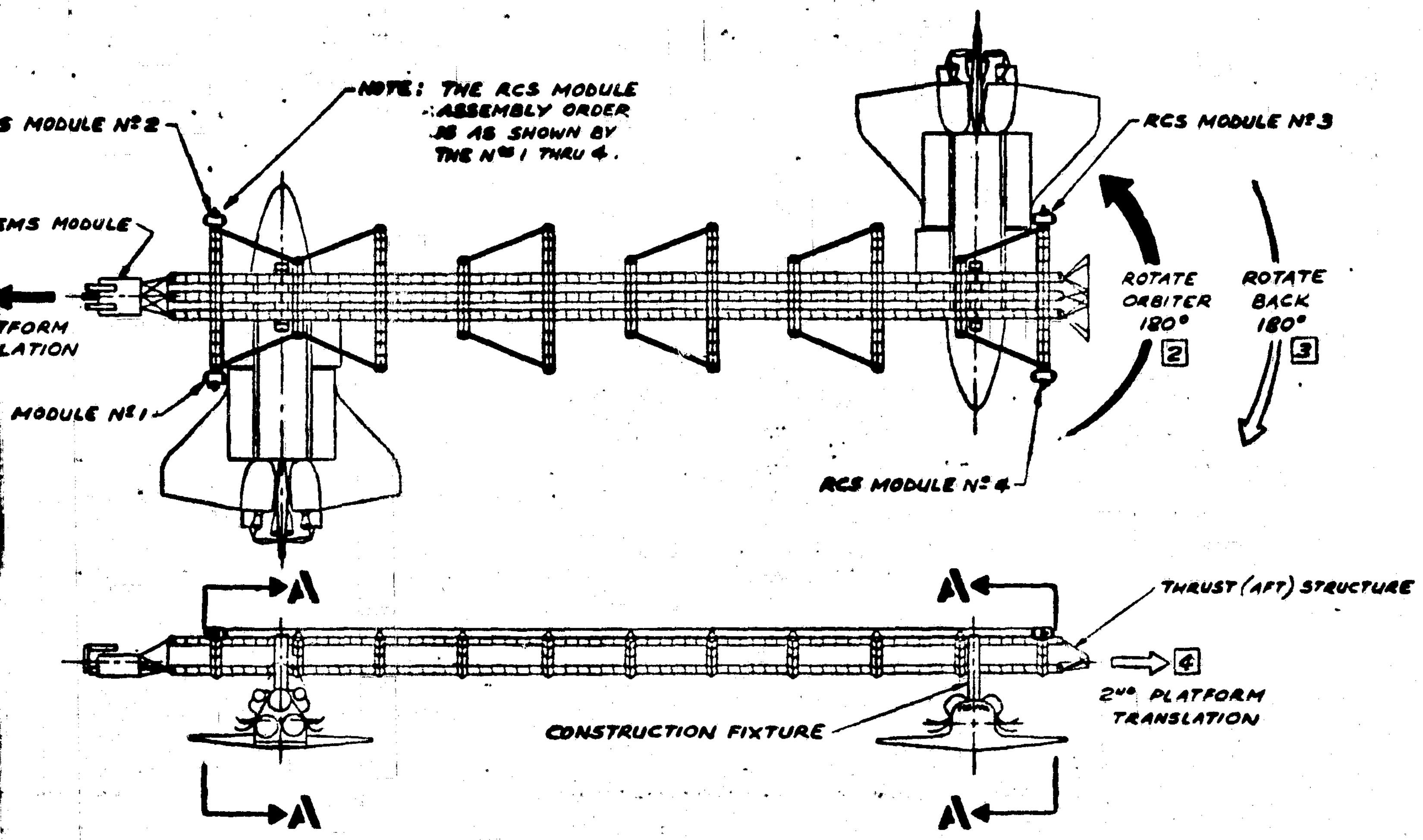
SECTION 13 – 13

RCS MODULE REMOVAL

SCALE: 1/40



5 FOLDOUT FRAME



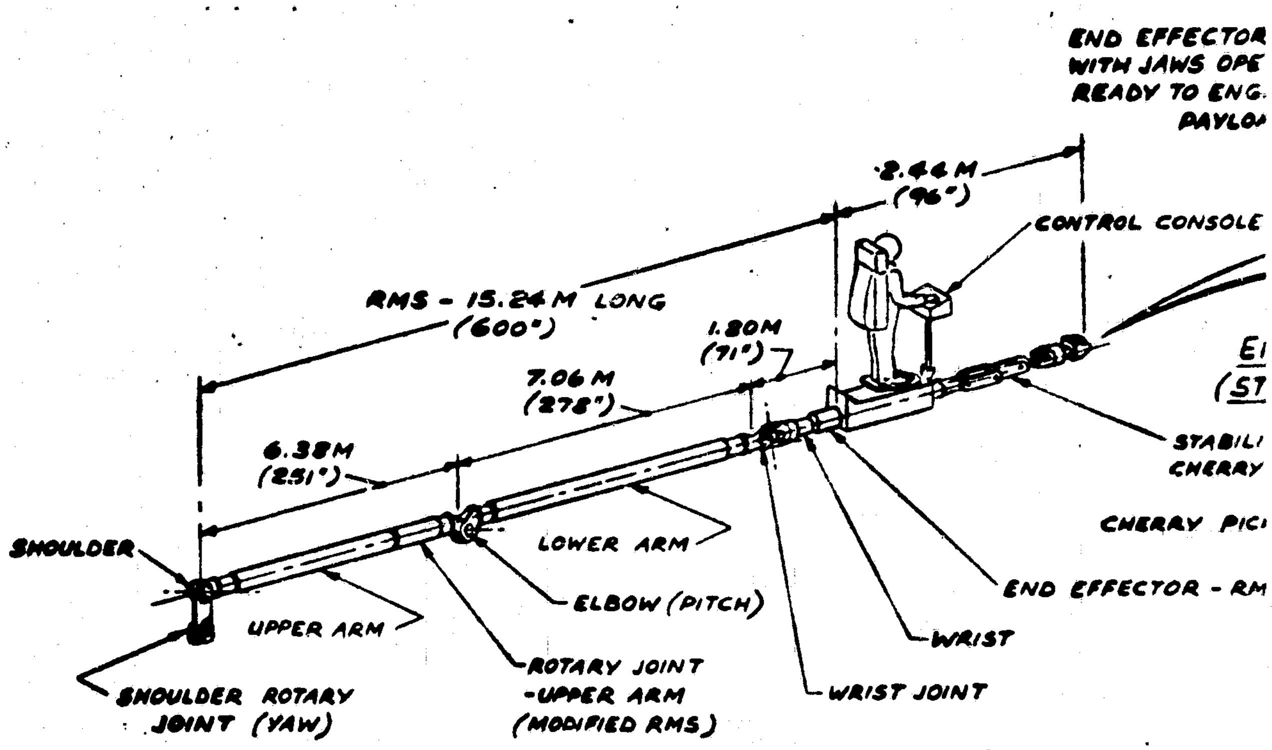
RELATIONSHIP OF ORBITER TO PLATFORM FOR RCS MODULE ATTACHMENT

NOTE: ITEMS 1 & 2 REQUIRED FOR ASSEMBLY OF RCS MODULES N° 3 & N° 4.
ITEMS 3 & 4 RETURNS ORBITER BACK TO THE SYSTEMS MODULE END FOR THE NEXT (CHECK-OUT) PROCEDURE.

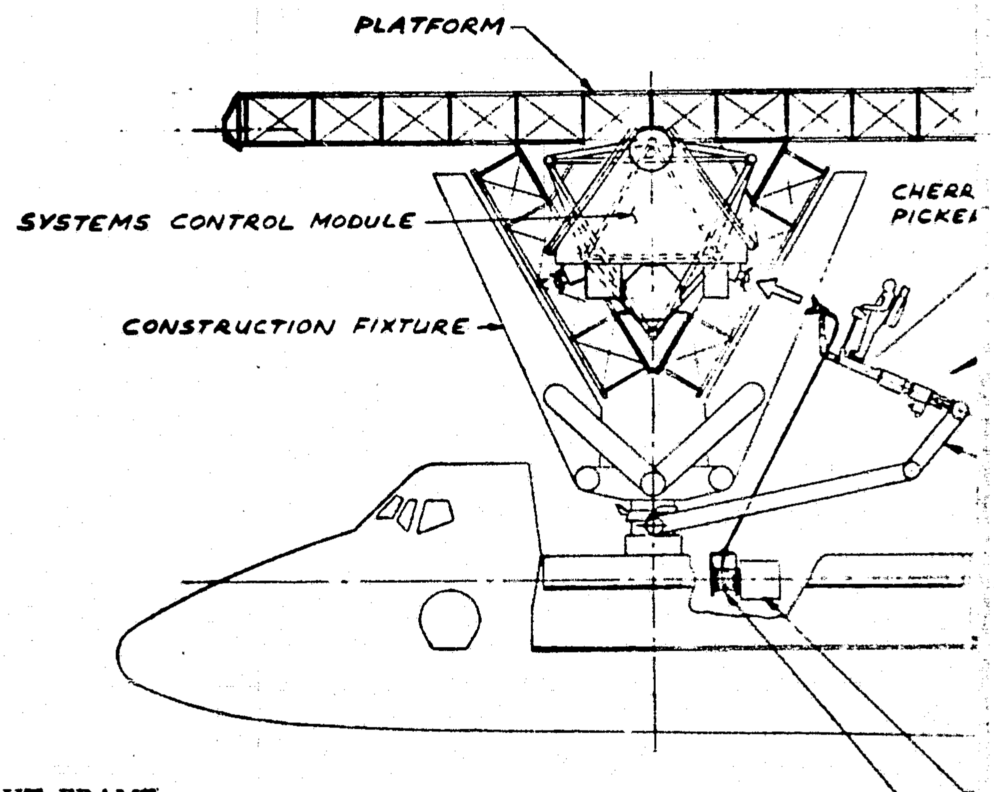
FOLDOUT FRAME

A-41,
A-42

SCALE 1/80	DR BUCK; DATE 1/21/81; MODEL SCSA	Rockwell International	
RCS MODULE INSTALLATION VIA., CHERRY PICKER			42662-65



RMS / CHERRY PICKER ASSEMBLY



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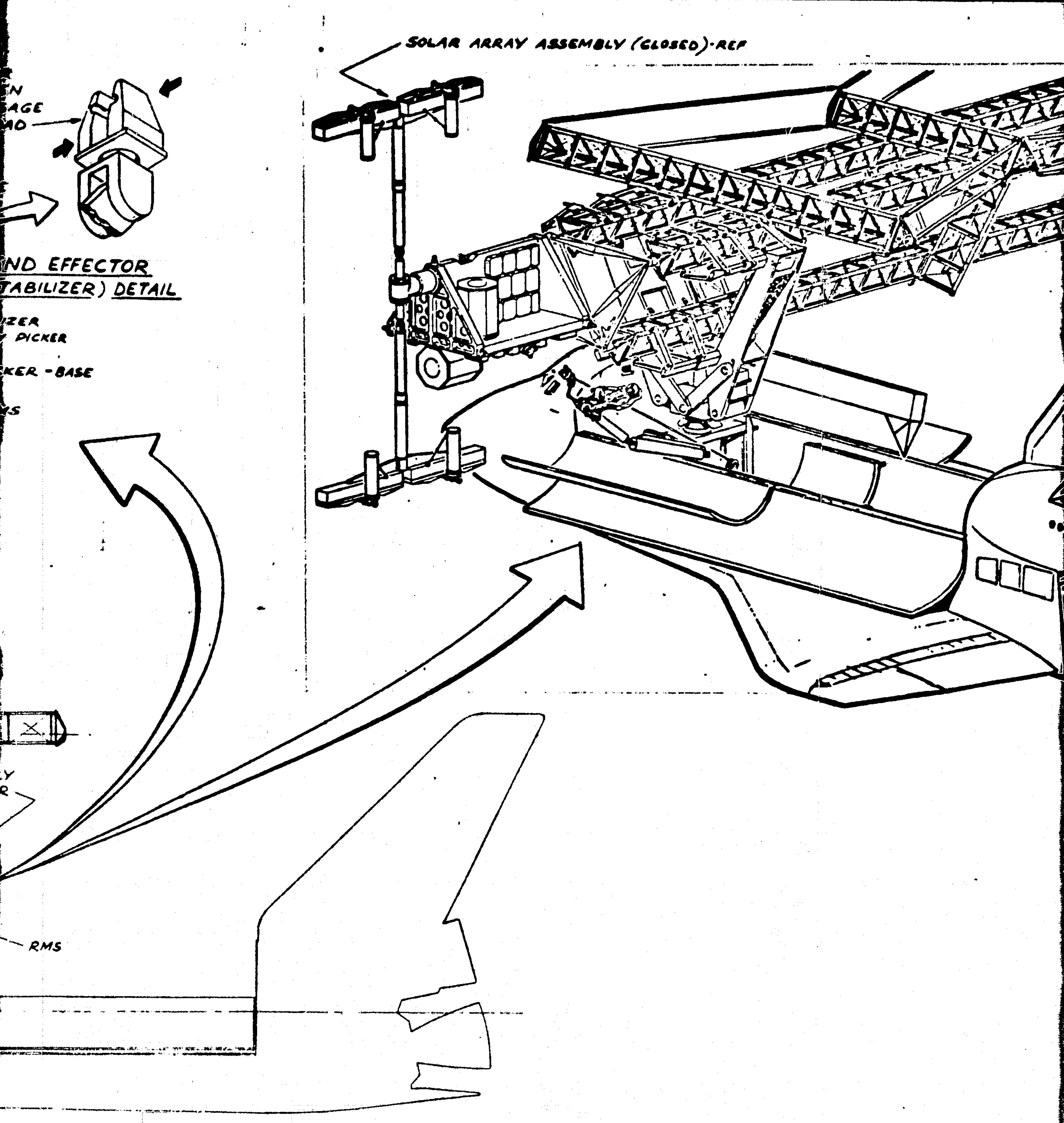
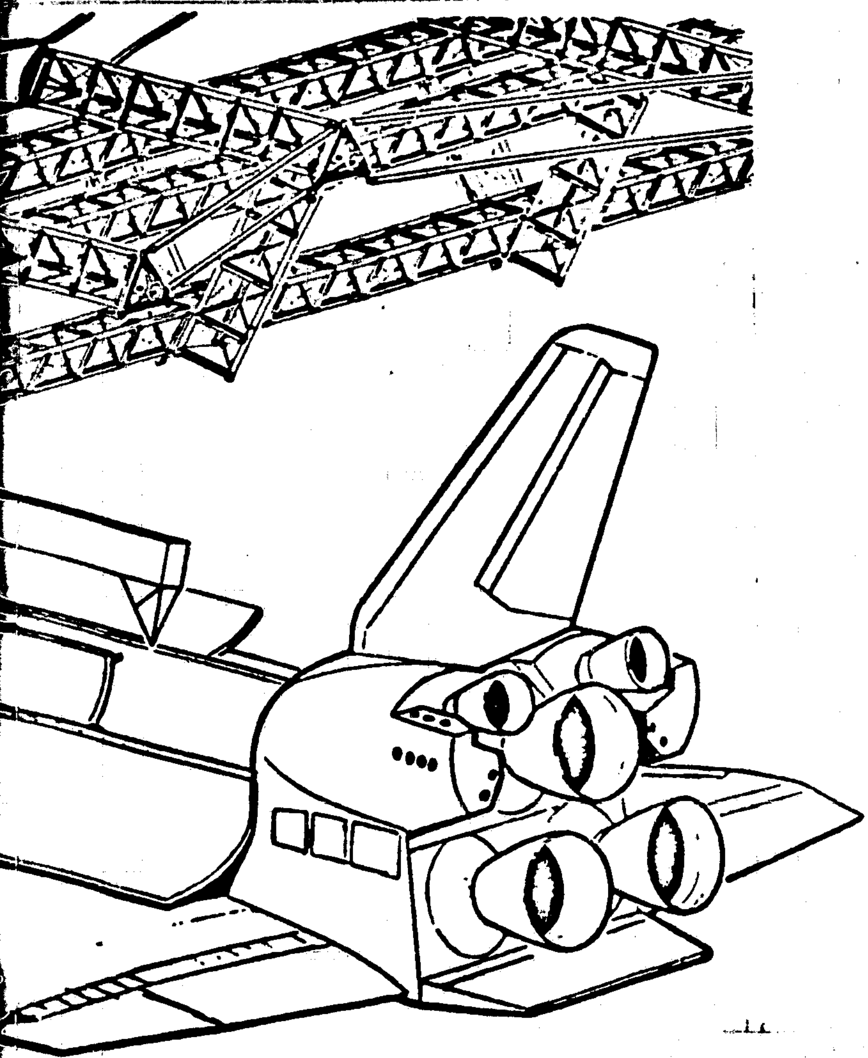
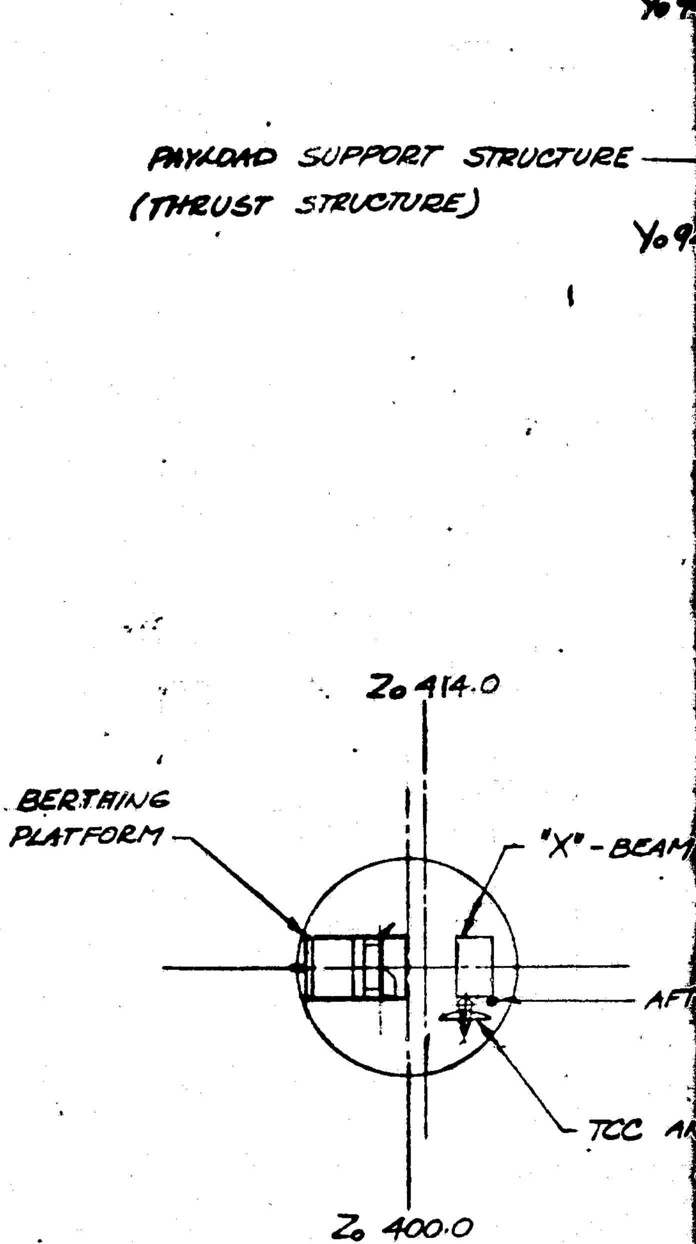
DETAIL H



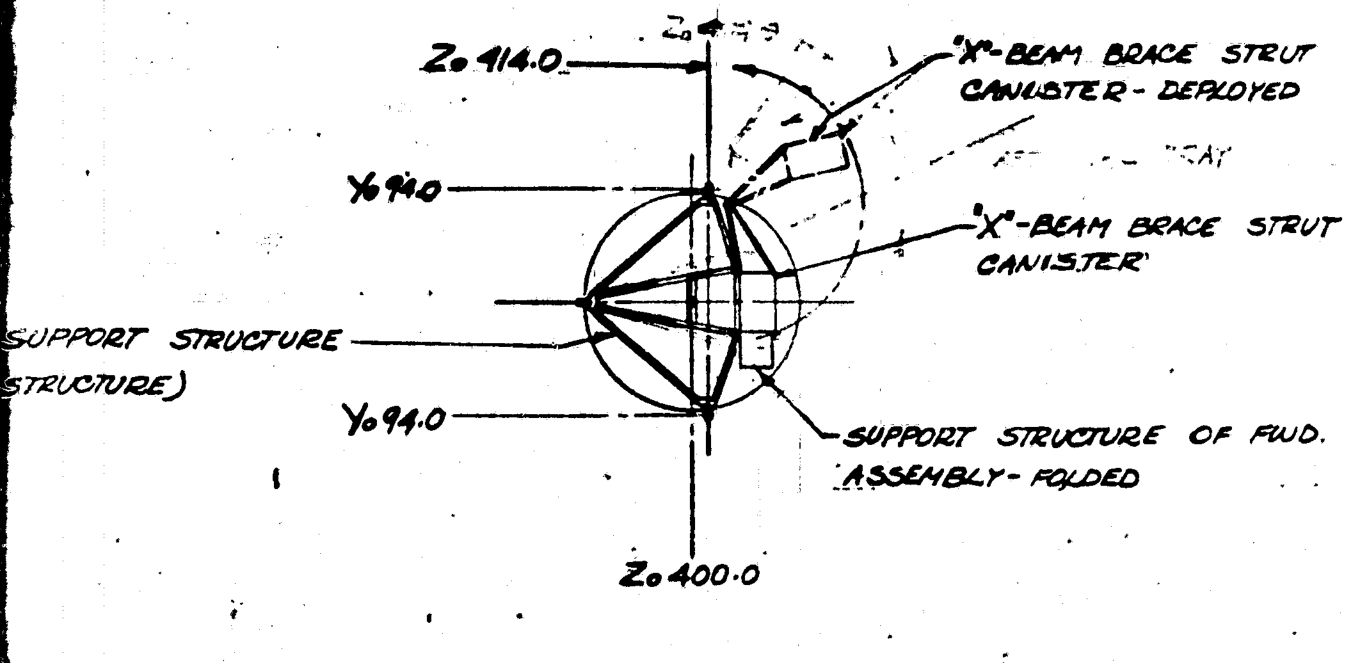
PLATFORM SYSTEMS CHECK - OUT UNIT

OWER CABLE UMBILICAL STORAGE REEL

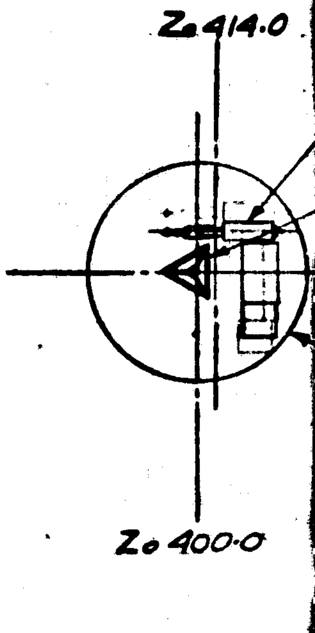



PAYLOAD SUPPORT STRUCTURE
(THRUST STRUCTURE)
Zo 414.0
BERTHING PLATFORM
TCC
Zo 400.0

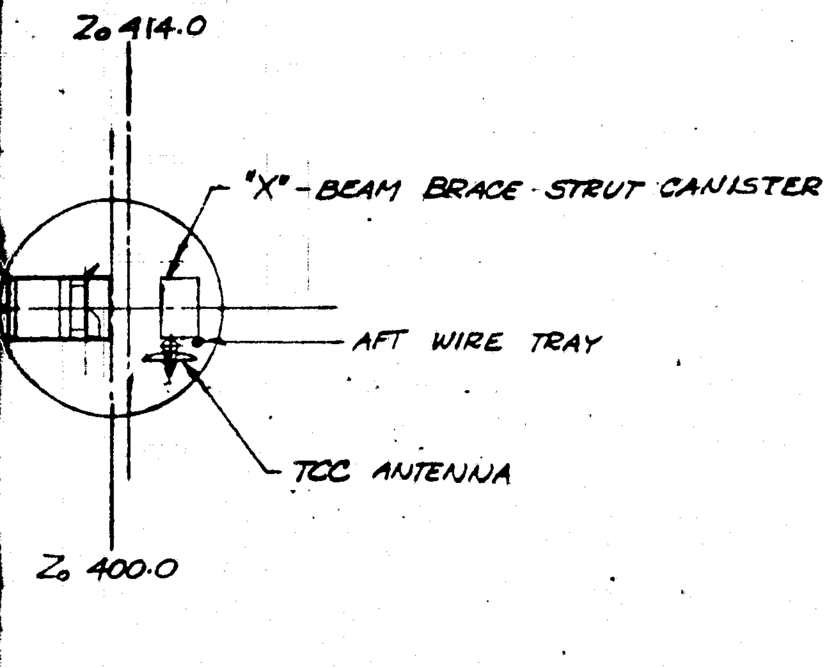
SECTION G-G



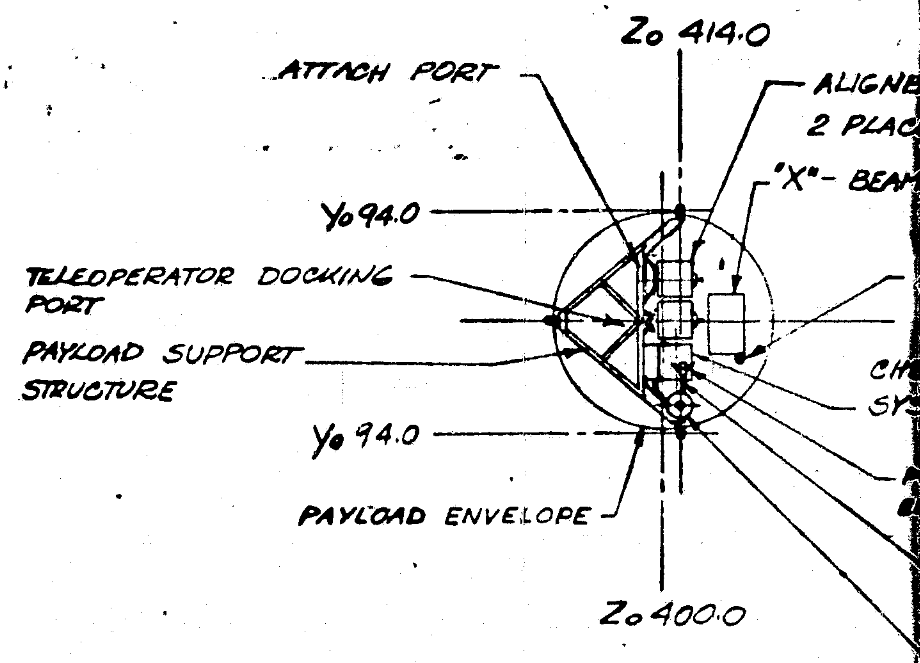
SECTION D-D



SECTION

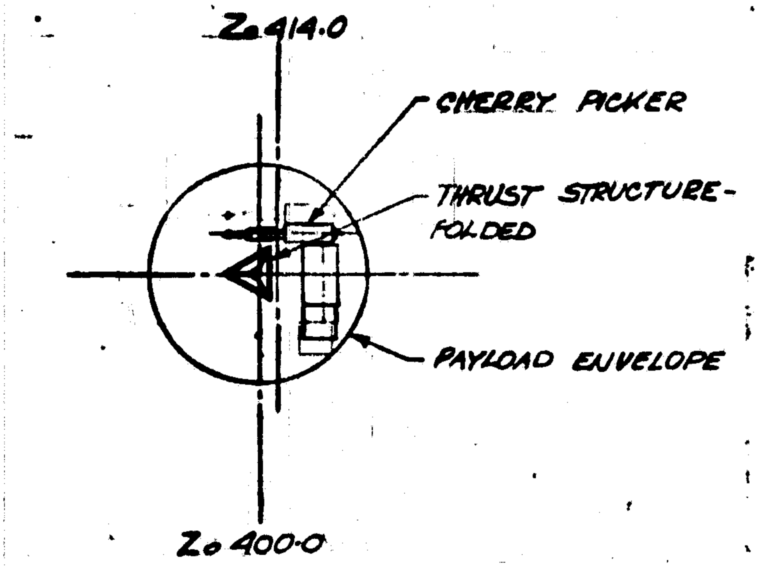


ECTION G-G

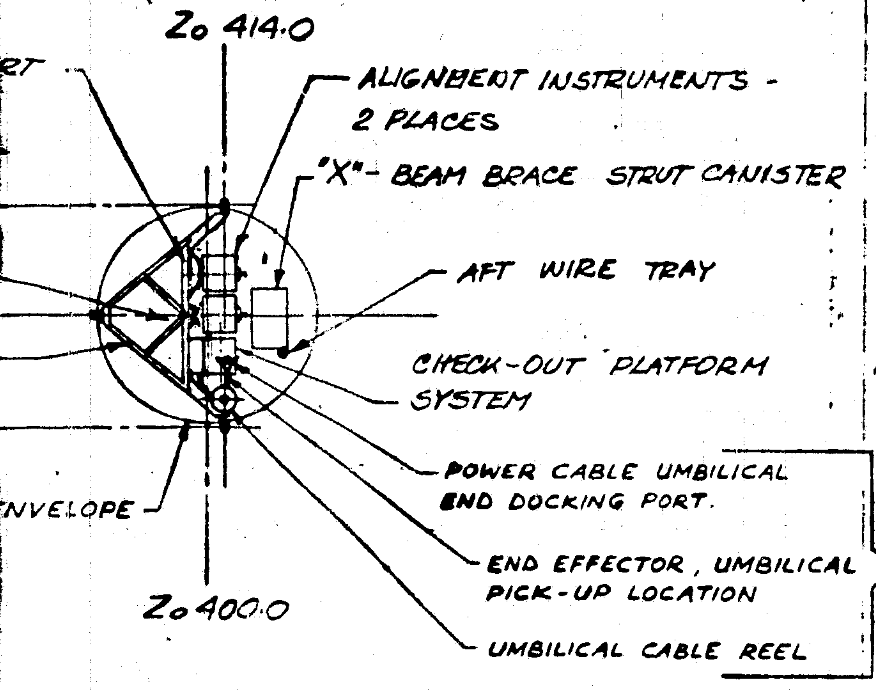


SECTION F-F

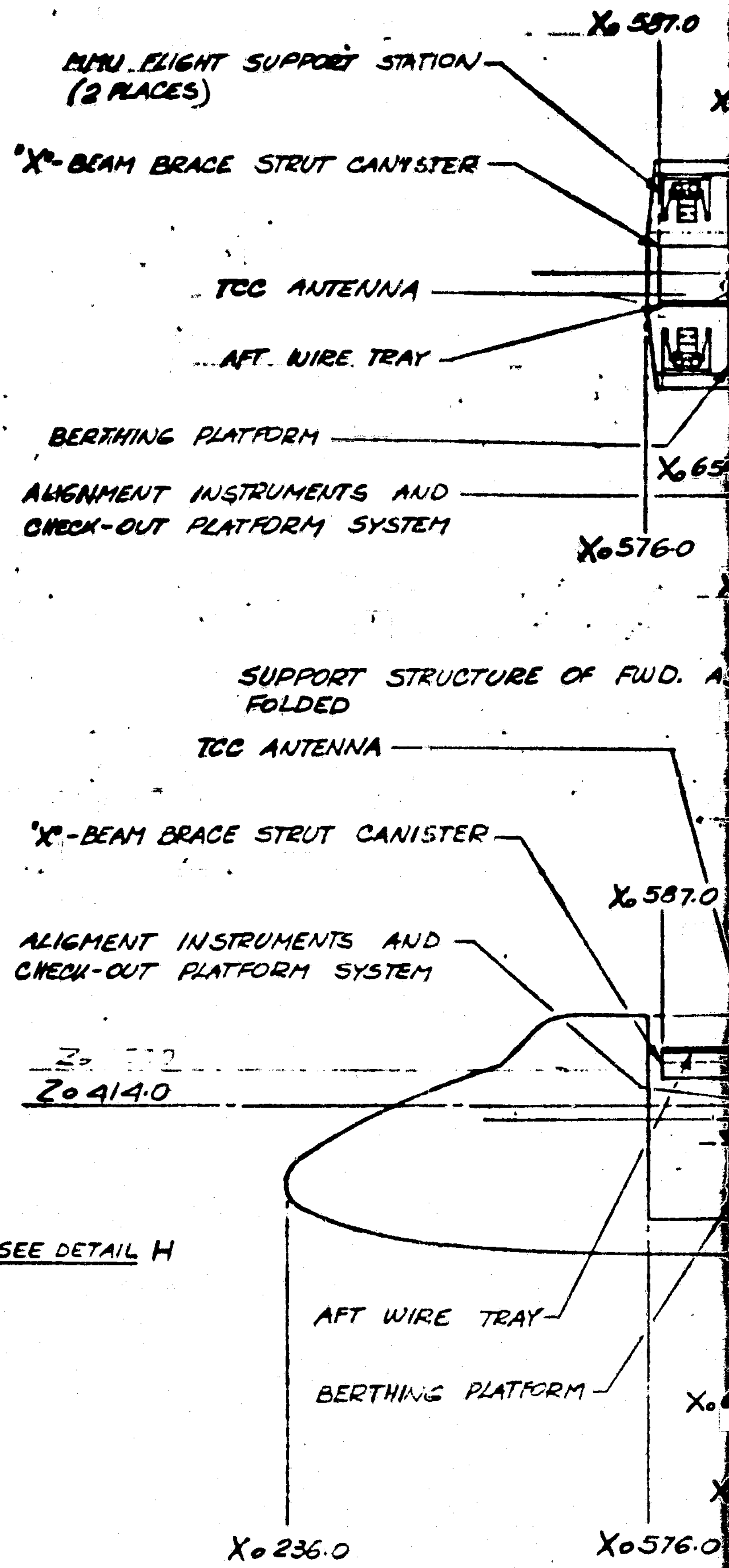
4 FOLDOUT FRAME

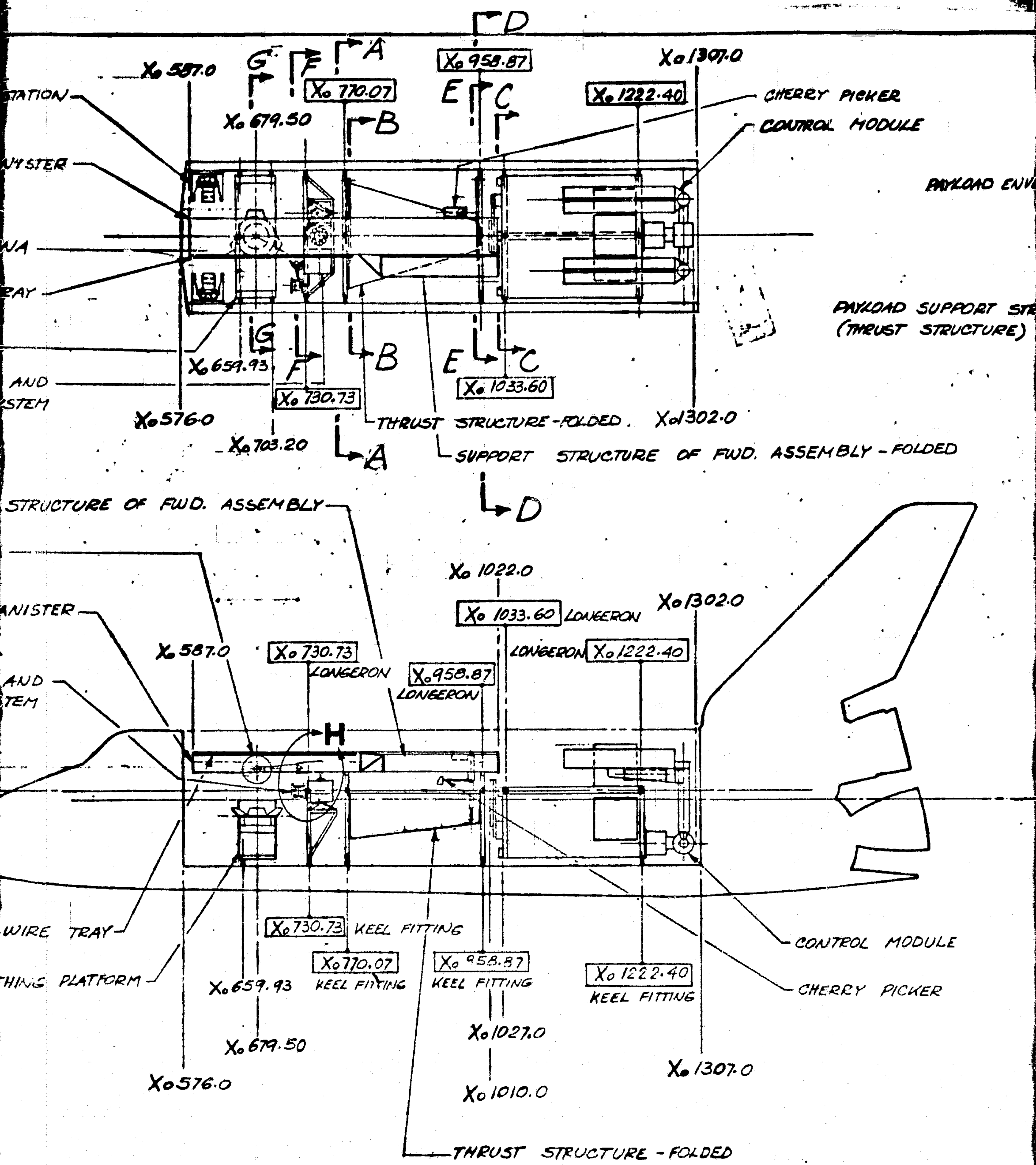


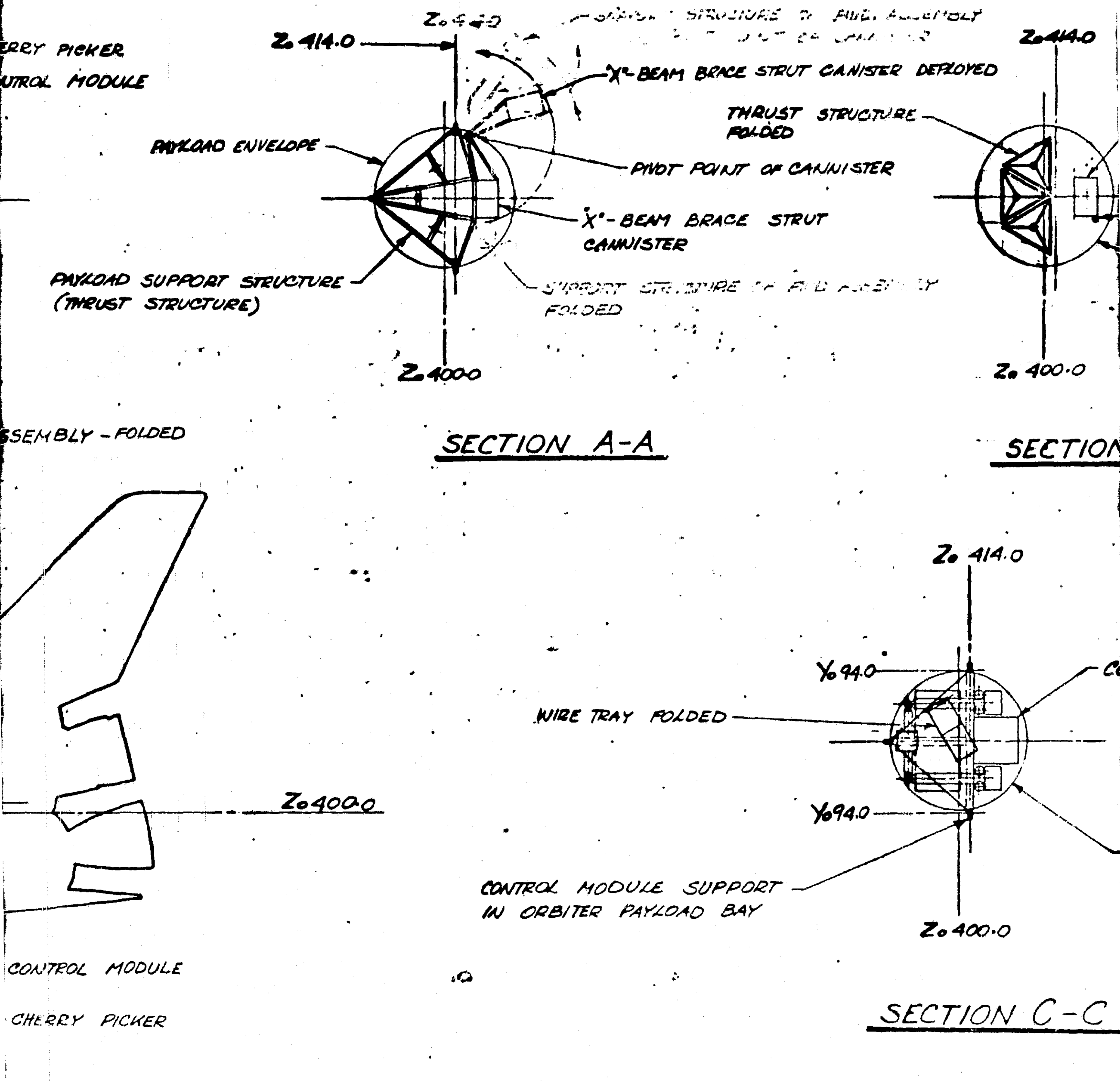
SECTION E-E



SECTION F-F




D
Xo 958.87
A
G
F
Xo 587.0
Xo 770.07
Xo 1307.0
STATION
E
C
Xo 1222.40
CHERRY PICKER
Xo 679.50
B
CONTROL MODULE
NISTER
PAYLOAD ENV
NA
RAY
PAYLOAD SUPPORT STR
(THRUST STRUCTURE)
Xo 659.93
AND
STEM
Xo 1033.60
Xo 730.73
Xo 576.0
THRUST STRUCTURE - FOLDED.
Xo 1302.0
Xo 703.20
SUPPORT STRUCTURE OF FWD. ASSEMBLY - FOLDED
STRUCTURE OF FWD. ASSEMBLY
Xo 1022.0
Xo 1302.0
ANISTER
Xo 1033.60 LONGERON
LONGERON
Xo 587.0
Xo 730.73
LONGERON
Xo 1222.40
Xo 958.87
LONGERON
AND
TEM
H
WIRE TRAY
Xo 730.73 KEEL FITTING
CONTROL MODULE
Xo 770.07
KEEL FITTING
Xo 958.87
KEEL FITTING
THING PLATFORM
Xo 659.93
Xo 1222.40
KEEL FITTING
CHERRY PICKER
Xo 1027.0
Xo 679.50
Xo 1307.0
Xo 576.0
Xo 1010.0
THRUST STRUCTURE - FOLDED



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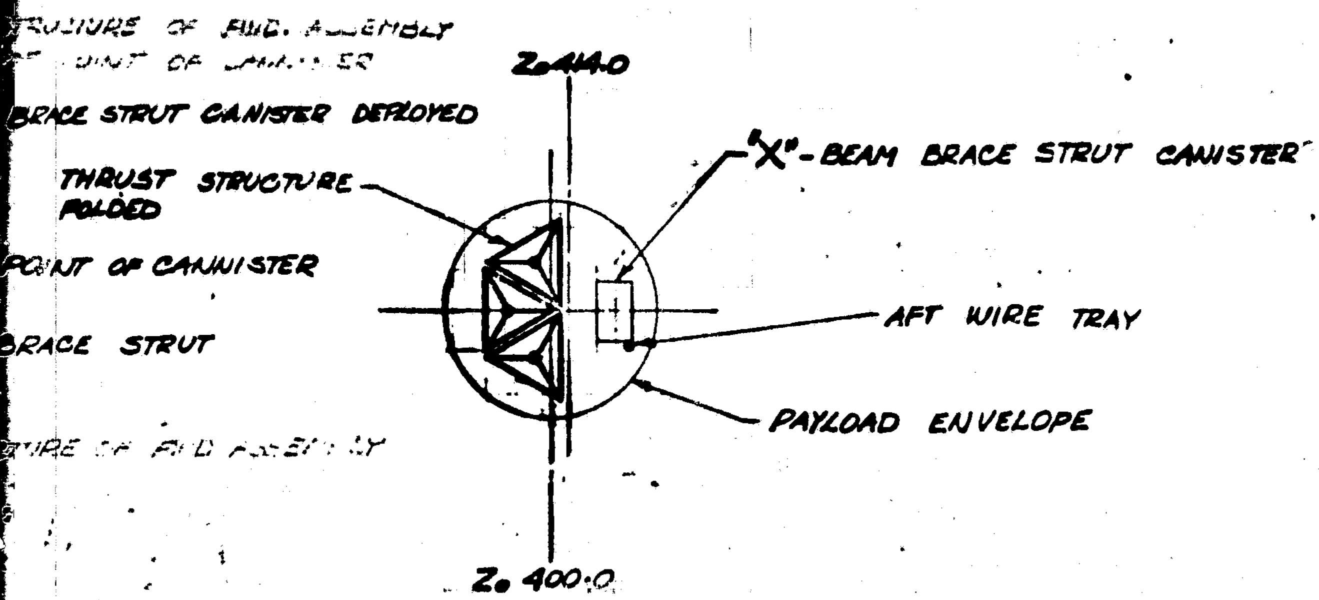
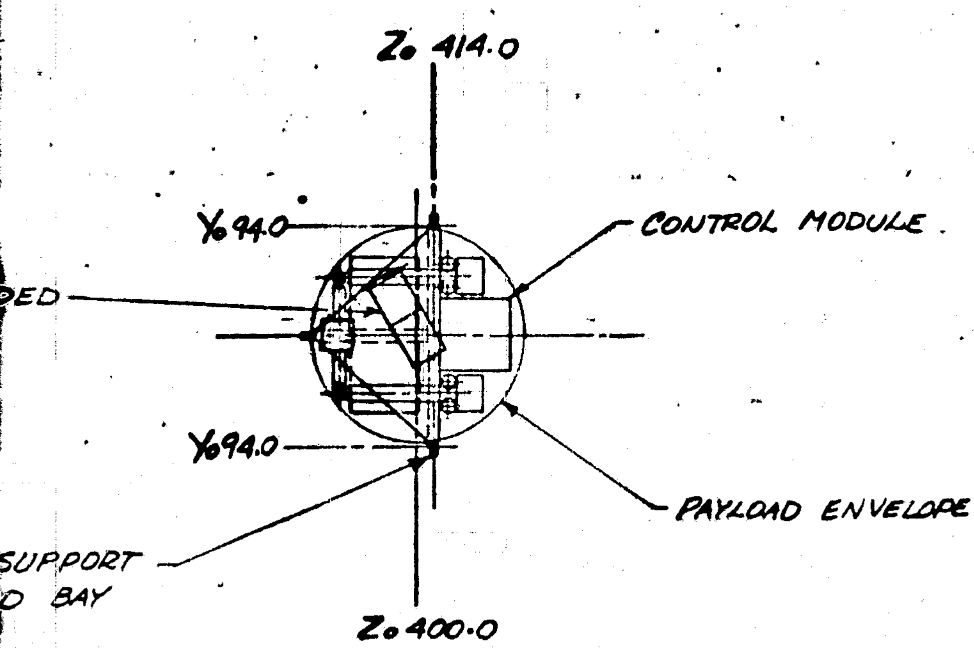


SECTION B-B



SECTION C-C

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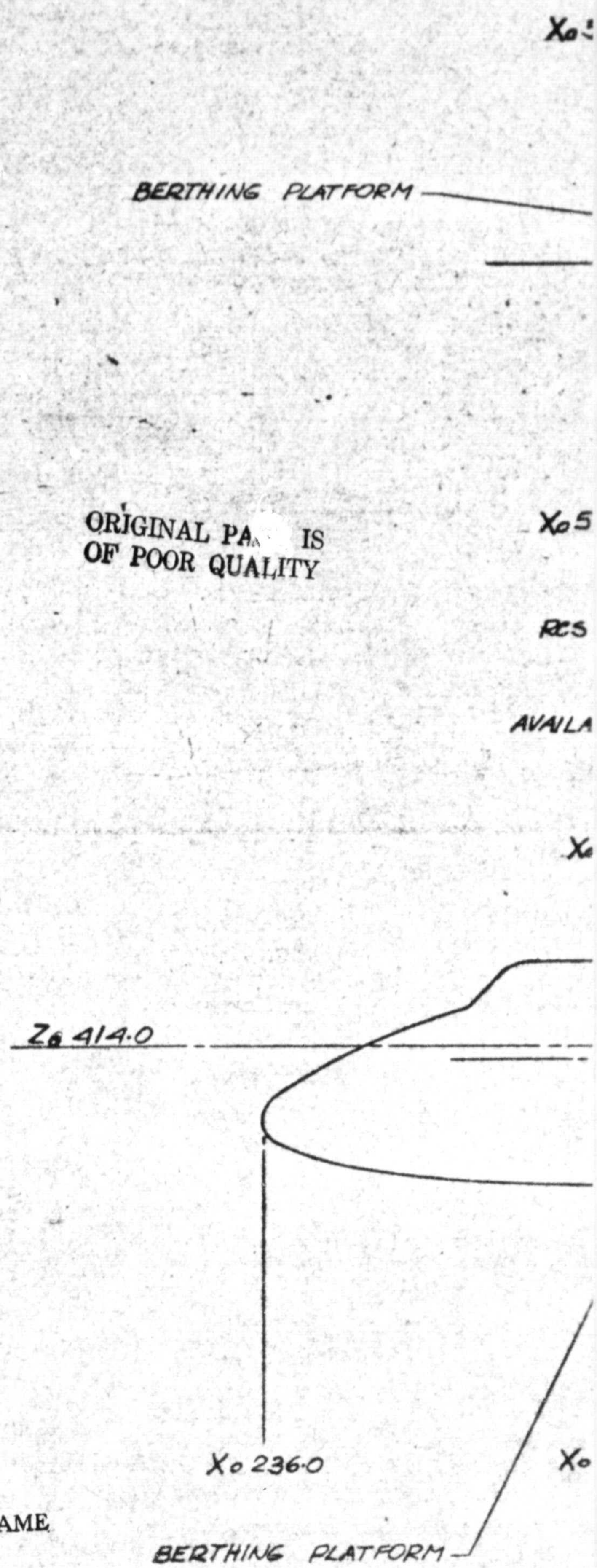
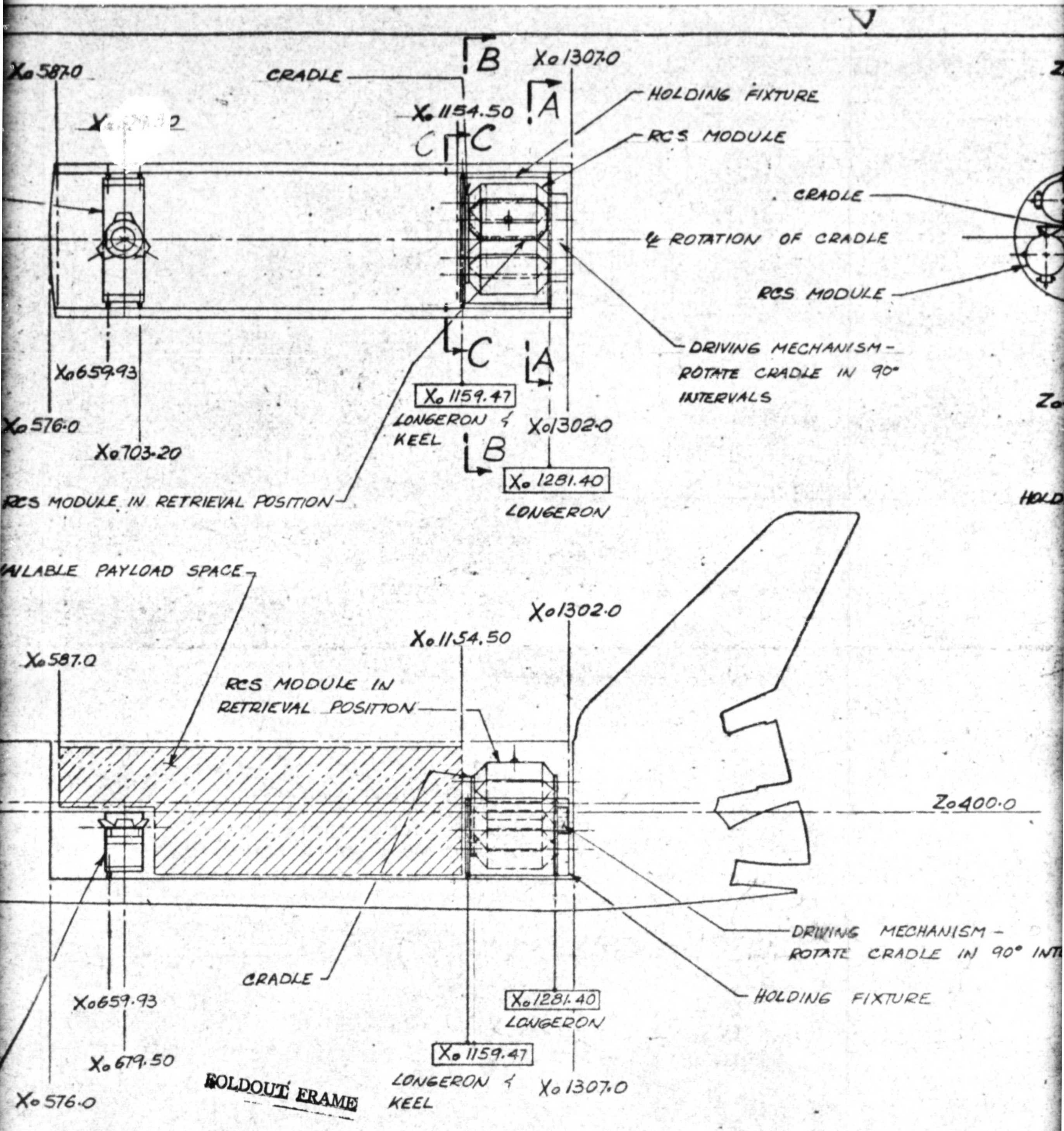
A-43,
A-44

SCALE 1/40	Rockwell International	
SHUTTLE BAY PACKAGING - SECOND FLIGHT		42662-67

FOLDOUT FRAME


BERTHING PLATFORM
RCS
Z_o 414.0
X_o 236.0
BERTHING PLATFORM



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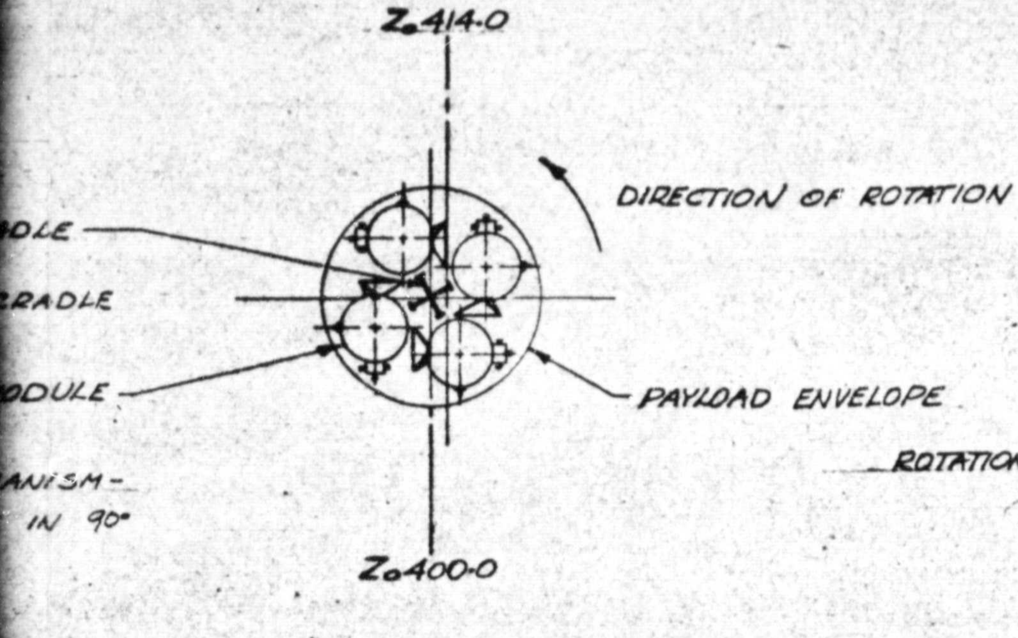
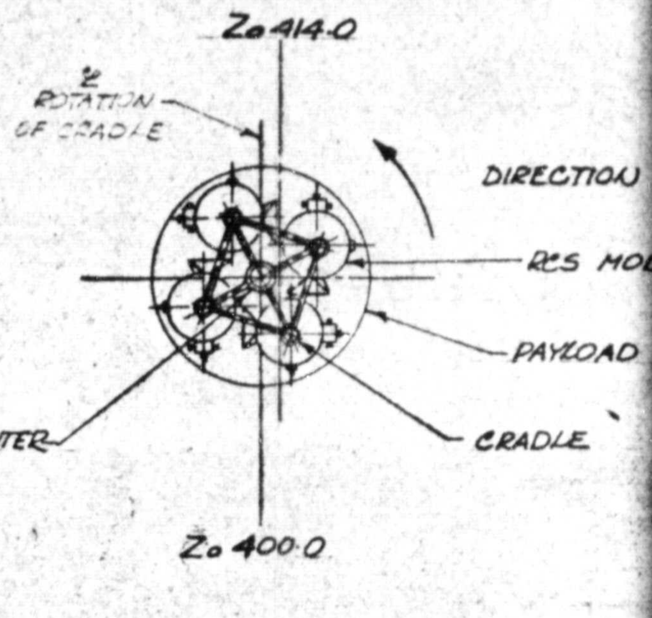


SECTION A-A

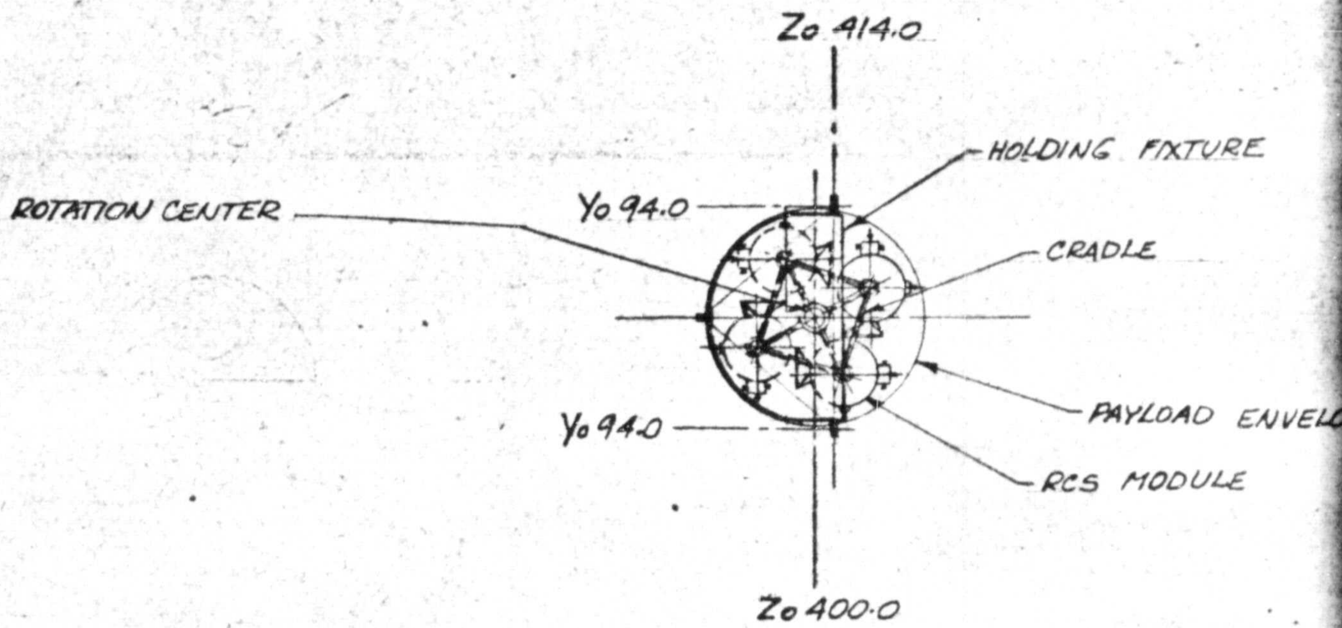
HOLDING FIXTURE OMITTED FOR CLARITY



SECTION B-B

HOLDING FIXTURE OMITTED FO

Zo 400.0



SECTION C-C

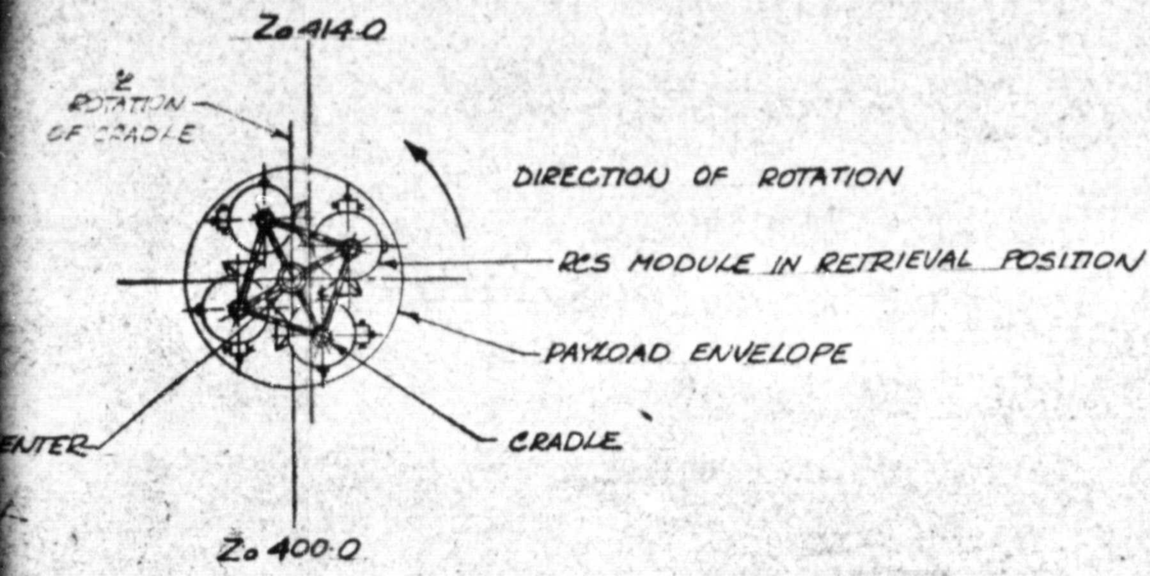
ING MECHANISM -
ATE CRADLE IN 90° INTERVALS

G FIXTURE

3

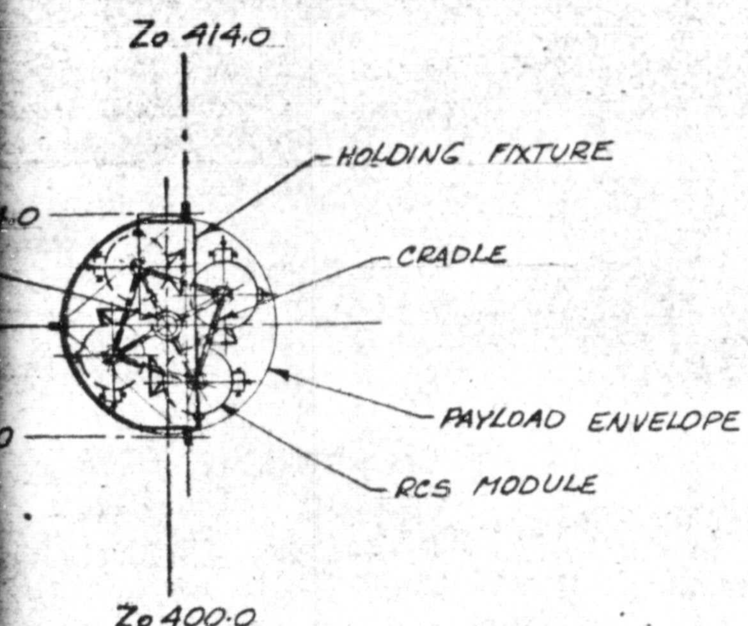
1/80

SHUT
THIR



SECTION B-B

HOLDING FIXTURE OMITTED FOR CLARITY



SECTION C-C

FOLDOUT FRAME

SHT 1 OF 3
A-45,
A-46

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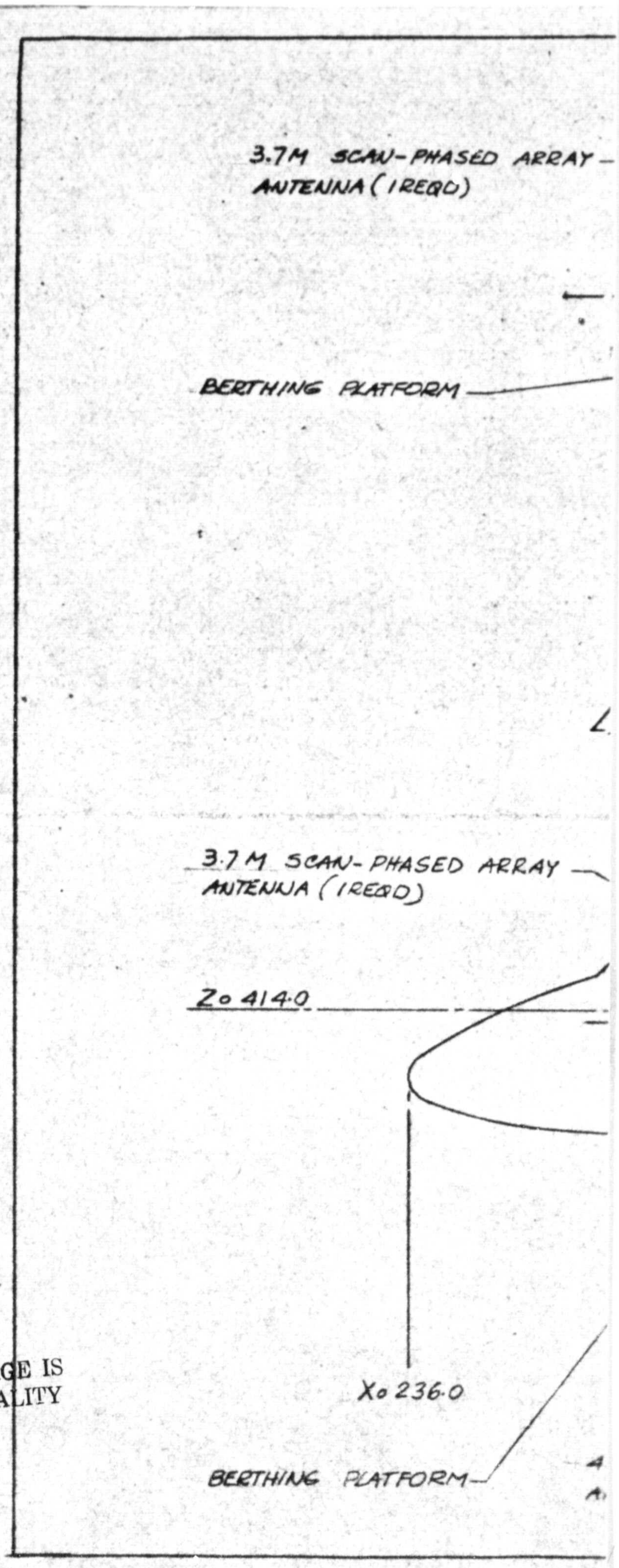
1/100	Rockwell International	
SHUTTLE BAY PACKAGING - THIRD FLIGHT		42662-68



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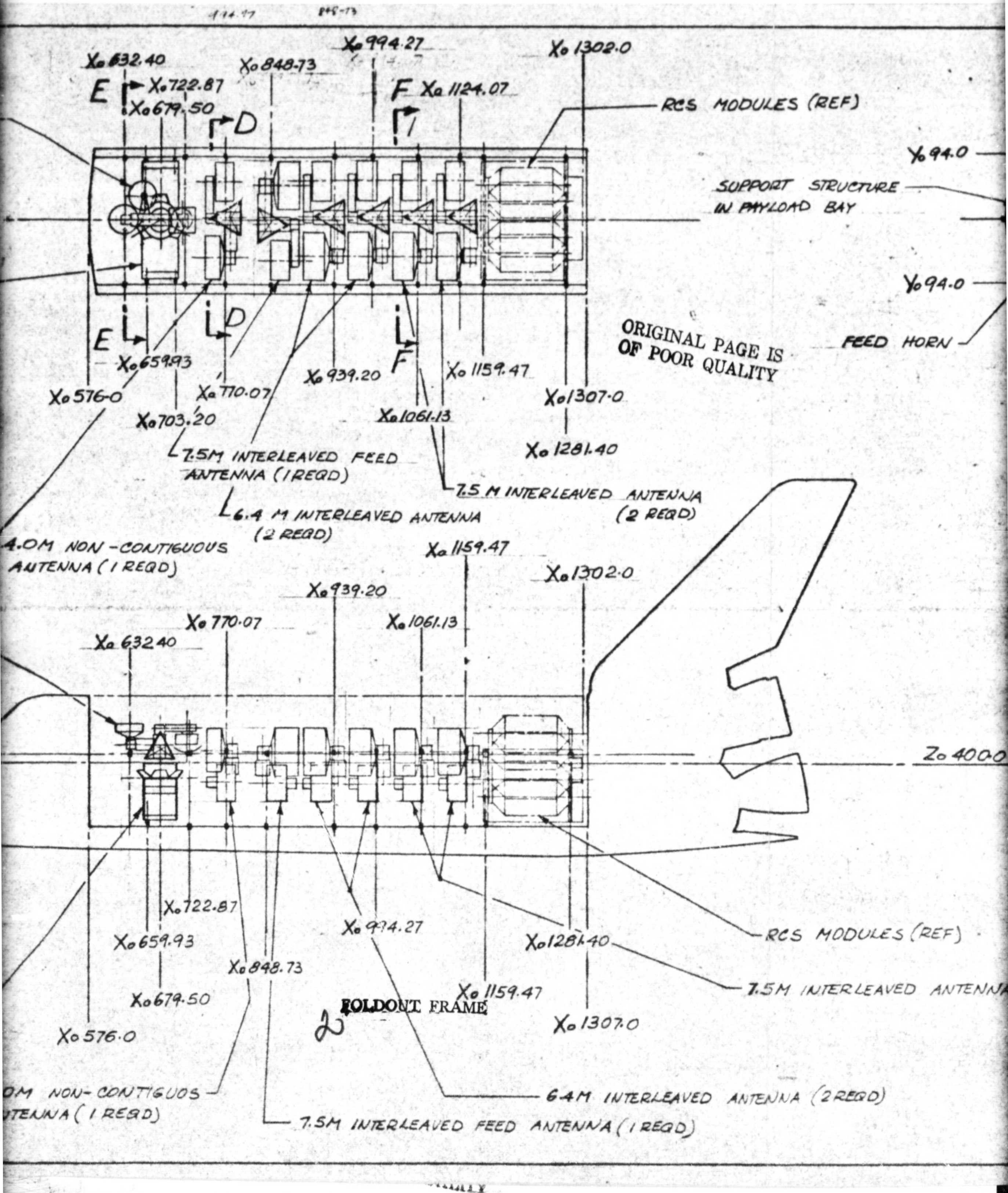
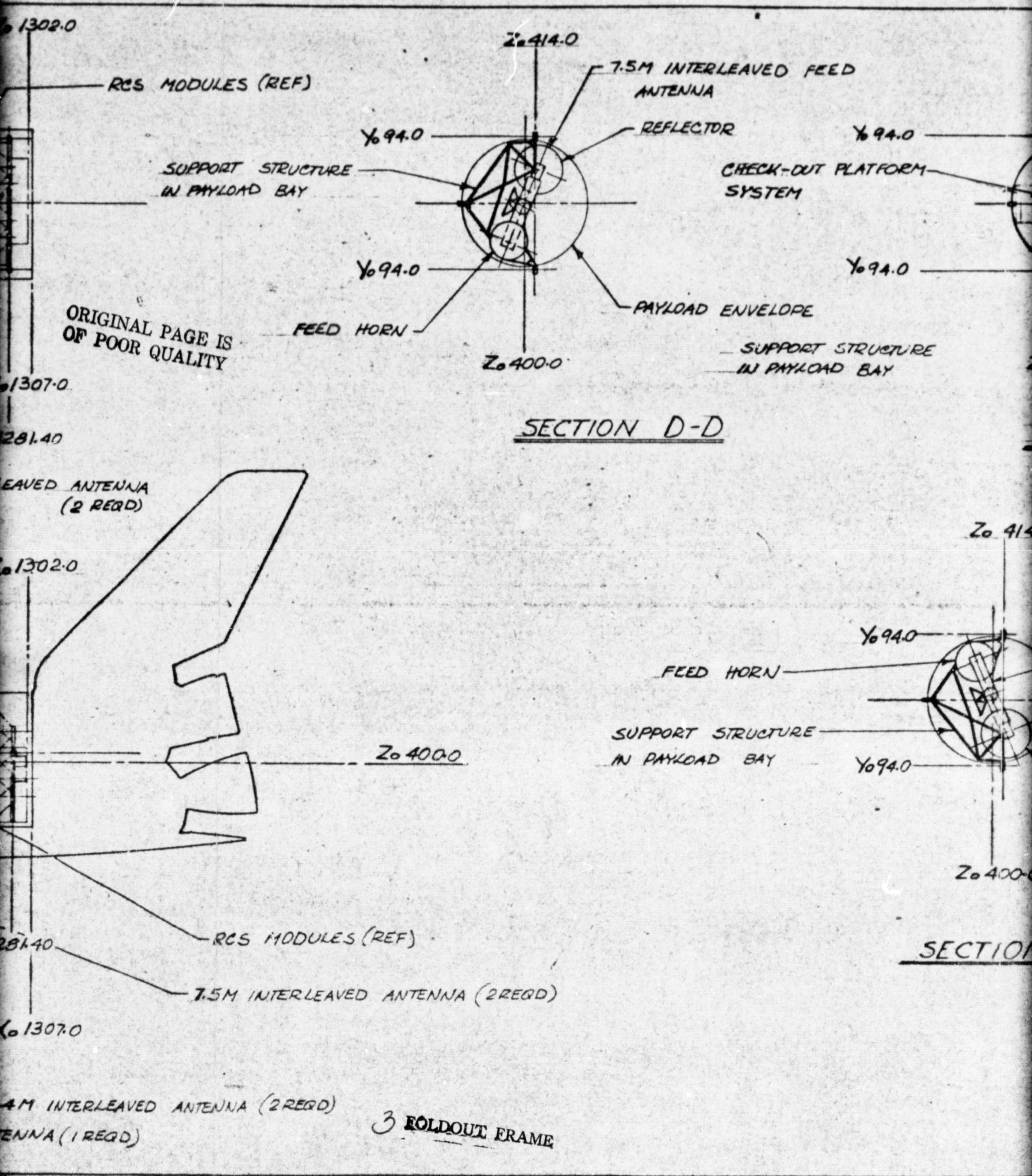
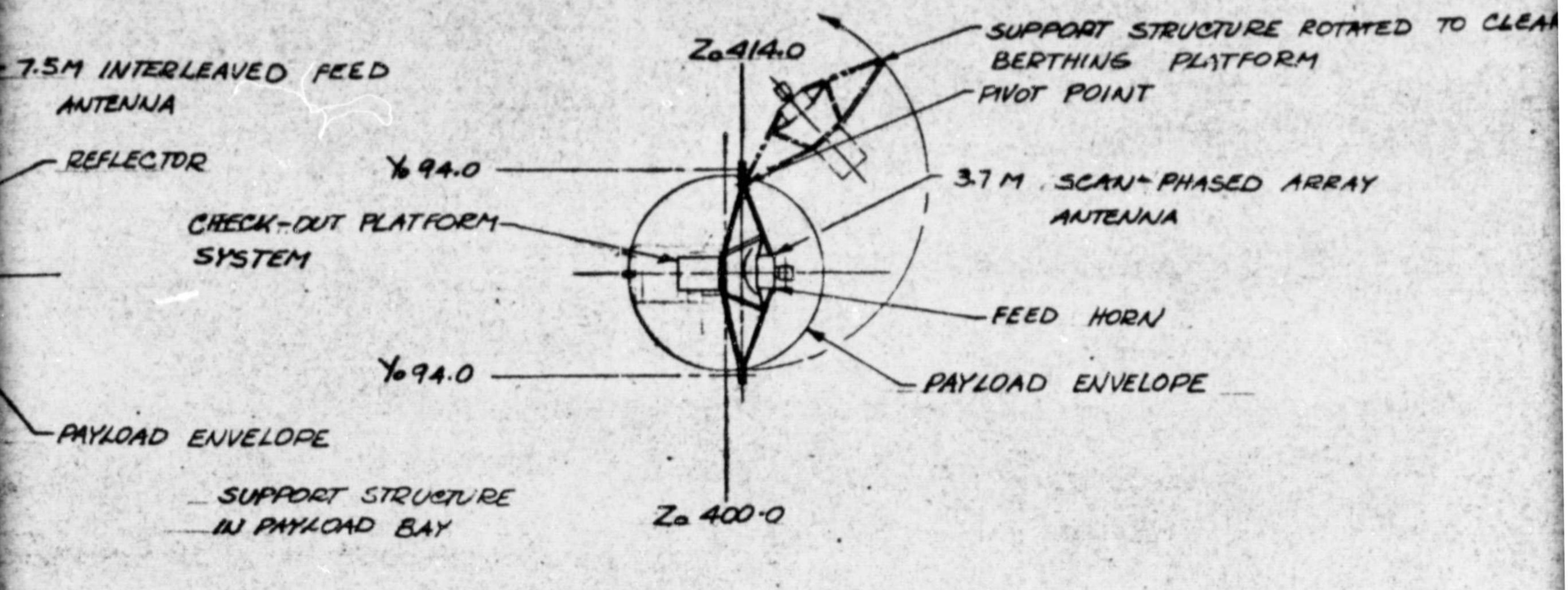

Xo 632.40
Xo 722.87
Xo 679.50
Xo 848.73
Xo 994.27
Xo 1124.07
Xo 1302.0
E
D
F
RCS MODULES (REF)
Yo 94.0
SUPPORT STRUCTURE IN PAYLOAD BAY
Yo 94.0
FEED HORN
Xo 659.93
Xo 576.0
Xo 770.07
Xo 703.20
Xo 939.20
Xo 1061.13
Xo 1159.47
Xo 1307.0
Xo 1281.40
7.5M INTERLEAVED FEED ANTENNA (1 REQD)
7.5 M INTERLEAVED ANTENNA (2 REQD)
6.4 M INTERLEAVED ANTENNA (2 REQD)
4.0M NON-CONTIGUOUS ANTENNA (1 REQD)
Xo 1159.47
Xo 1302.0
Xo 939.20
Xo 770.07
Xo 1061.13
Xo 632.40
Zo 400.0
Xo 722.87
Xo 994.27
Xo 659.93
Xo 1281.40
RCS MODULES (REF)
Xo 848.73
Xo 679.50
Xo 1159.47
7.5M INTERLEAVED ANTENNA
Xo 576.0
Xo 1307.0
OM NON-CONTIGUOS ANTENNA (1 REQD)
6.4M INTERLEAVED ANTENNA (2 REQD)
7.5M INTERLEAVED FEED ANTENNA (1 REQD)

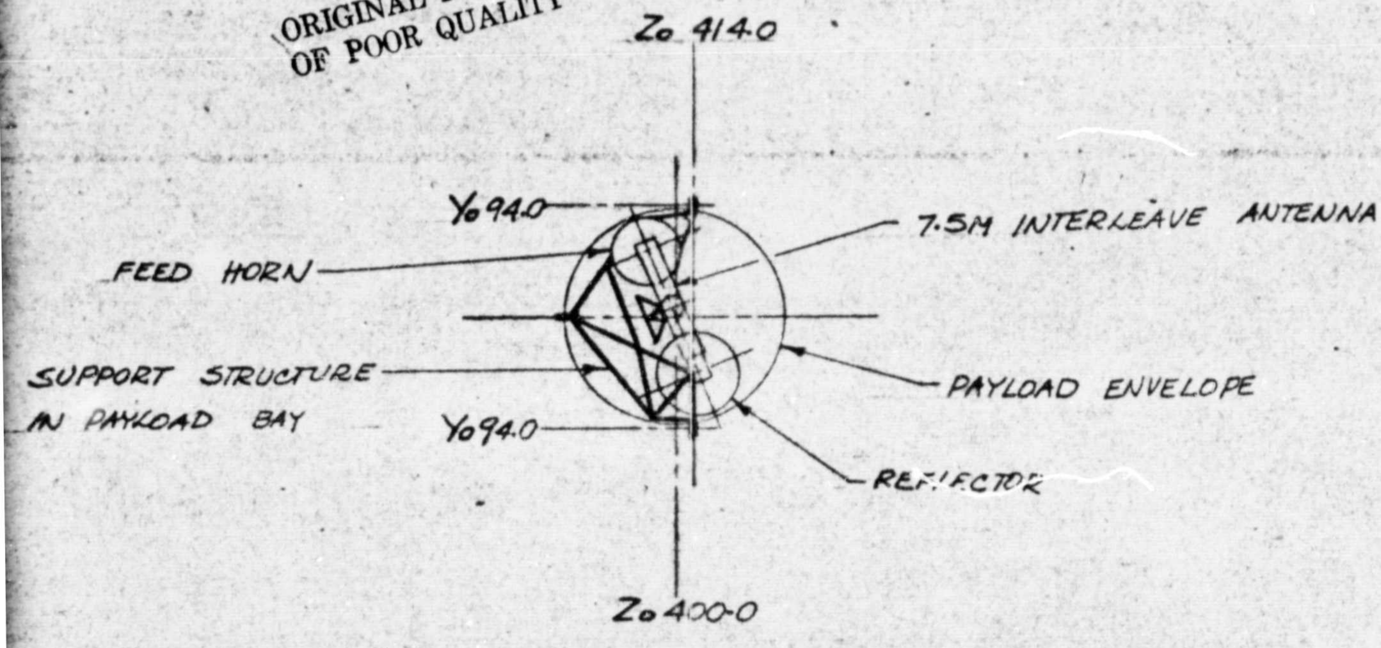


Yo 1302.0
RCS MODULES (REF)
Yo 1307.0
281.40
LEAVED ANTENNA
(2 REQD)
Zo 414.0
7.5M INTERLEAVED FEED
ANTENNA
REFLECTOR
Yo 94.0
SUPPORT STRUCTURE
IN PAYLOAD BAY
Yo 94.0
FEED HORN
PAYLOAD ENVELOPE
Zo 400.0
SUPPORT STRUCTURE
IN PAYLOAD BAY
Yo 94.0
CHECK-OUT PLATFORM
SYSTEM
Yo 94.0
SECTION D-D
Yo 1302.0
Zo 400.0
RCS MODULES (REF)
281.40
7.5M INTERLEAVED ANTENNA (2REQD)
Yo 1307.0
Zo 414
Yo 94.0
FEED HORN
SUPPORT STRUCTURE
IN PAYLOAD BAY
Yo 94.0
Zo 400.0
SECTION
4M INTERLEAVED ANTENNA (2 REQD)
ENNA (1 REQD)



ON D-D

SECTION E-E



SECTION F-F

SHT 2
A-47,

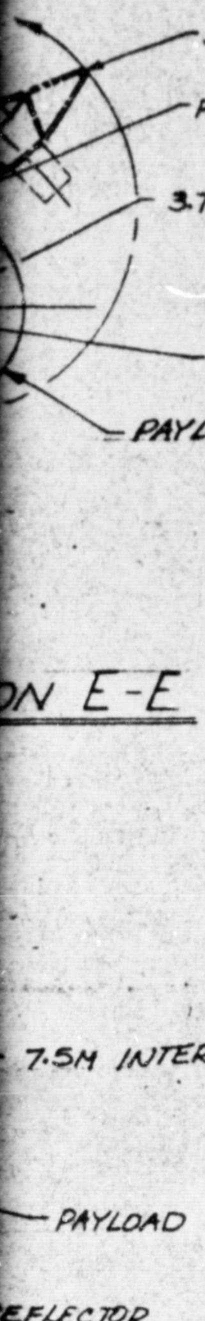
1/80

Rockwell International

SHUTTLE BAY PACKAGING - THIRD FLIGHT

4266

FOLDOUT FRAME



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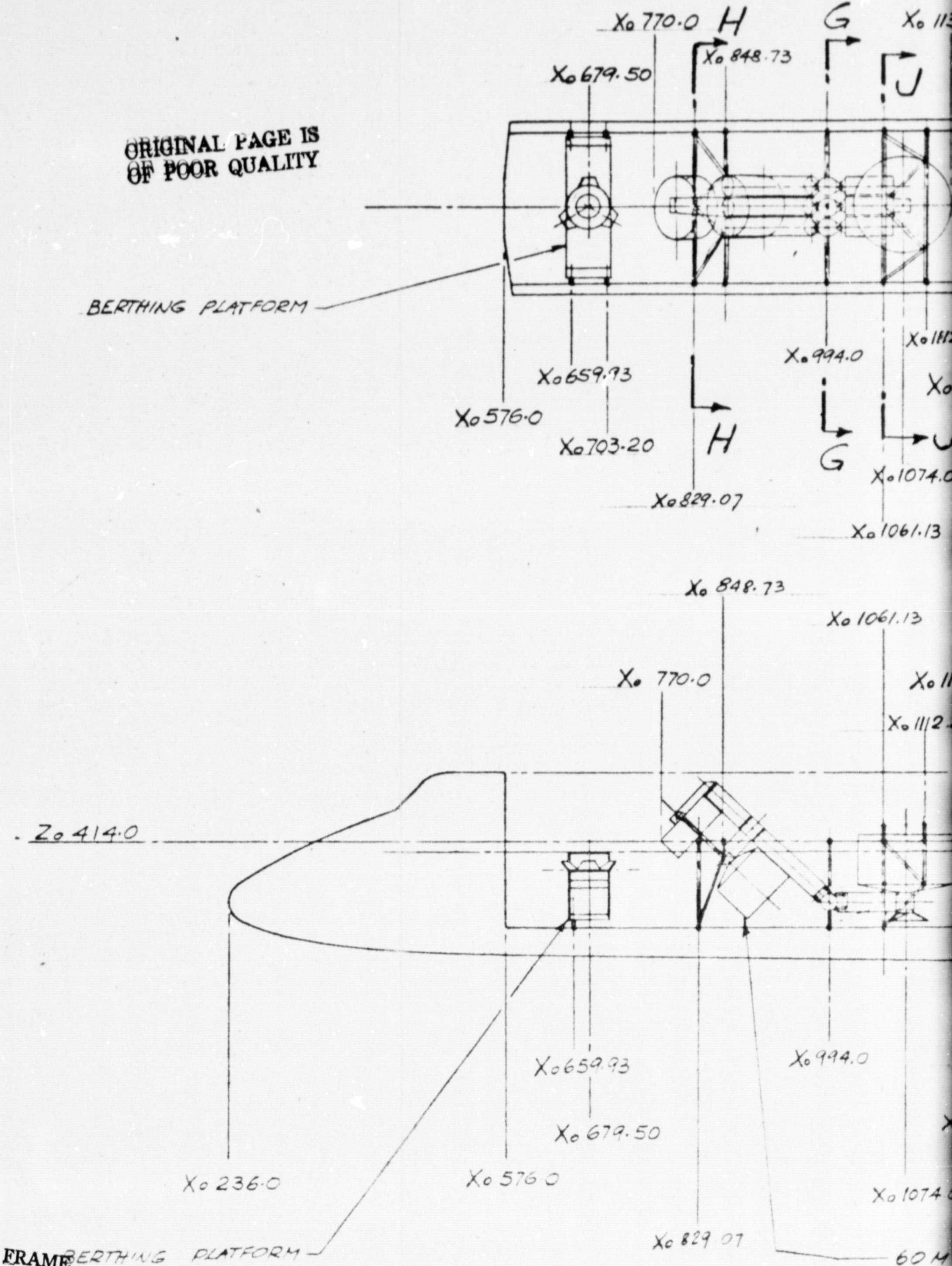
SHT 2 OF 3
A-47, A-48

SCALE 1/80	Rockwell International		
SHUTTLE BAY PACKAGING - THIRD FLIGHT		42662-68	


Xo 770.0
H
G
Xo 848.73
Xo 679.50
J
BERTHING PLATFORM
Xo 659.93
Xo 994.0
Xo 576.0
Xo 703.20
H
G
Xo 1074.0
Xo 829.07
Xo 1061.13
Xo 848.73
Xo 1061.13
Xo 770.0
Zo 414.0
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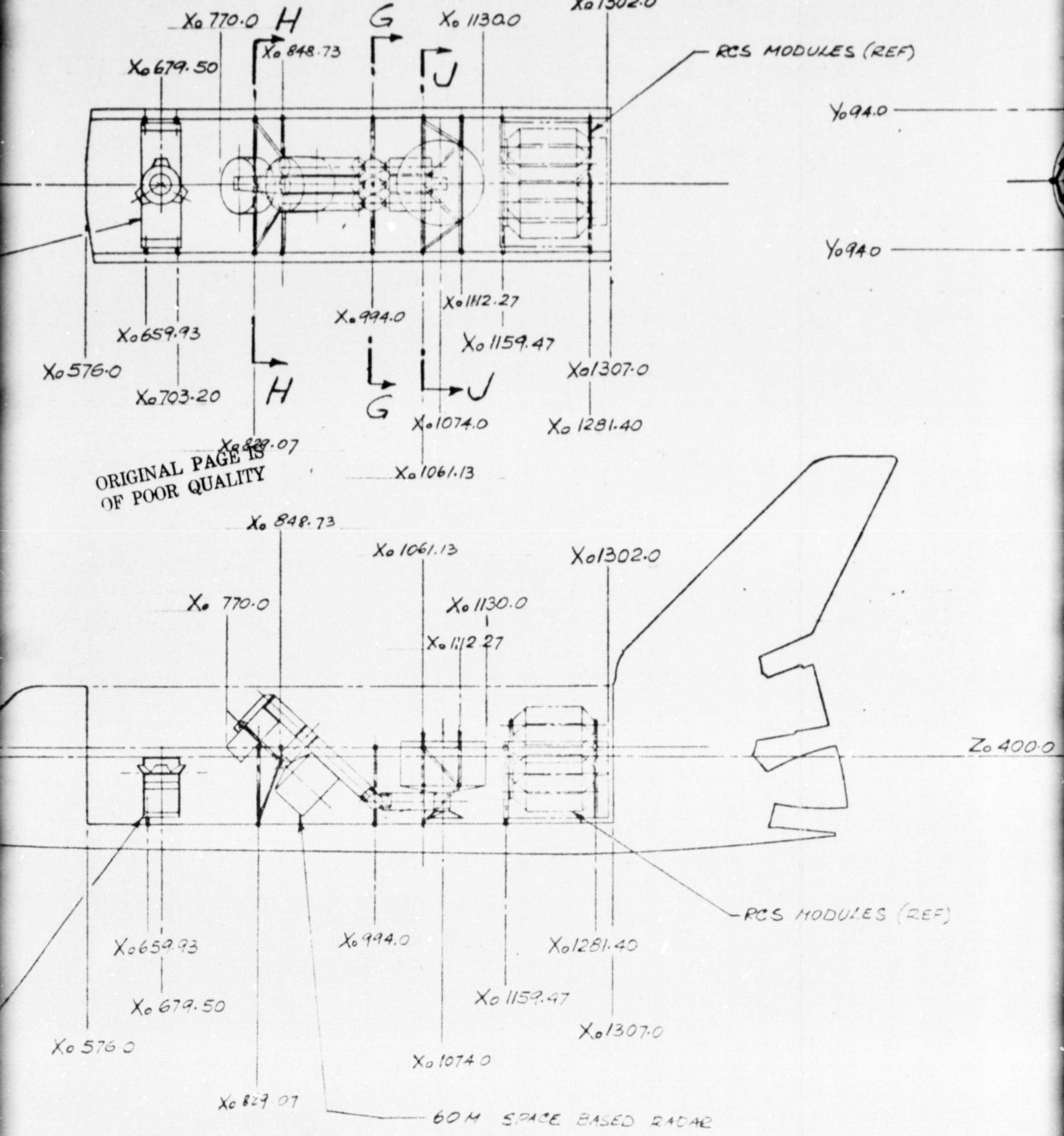
Xo 236.0
Xo 576.0
Xo 829.07
BERTHING PLATFORM



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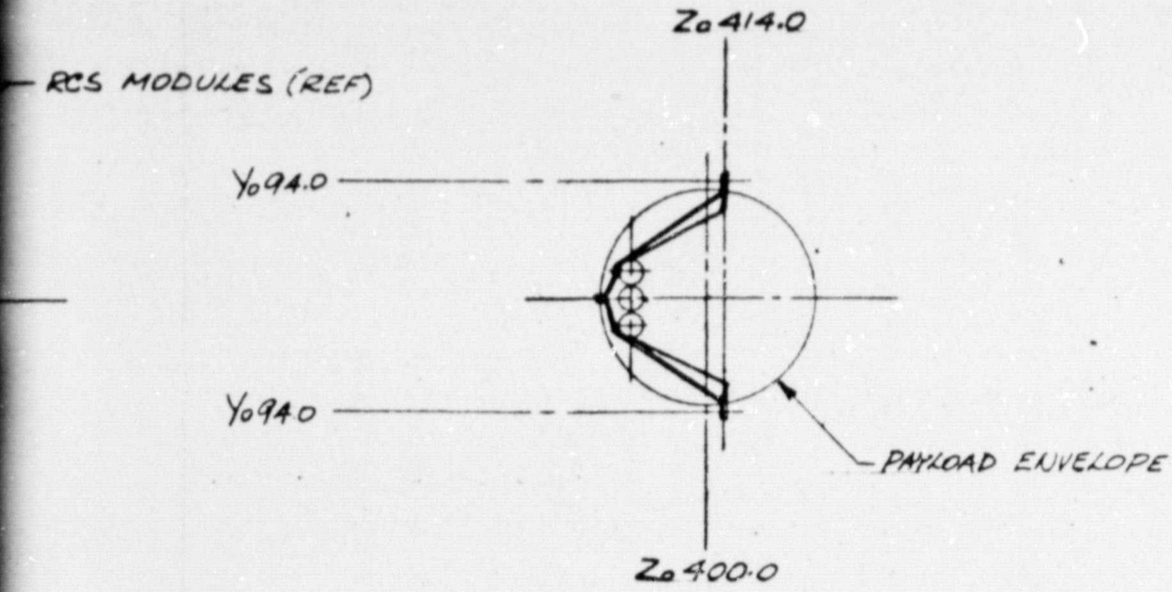
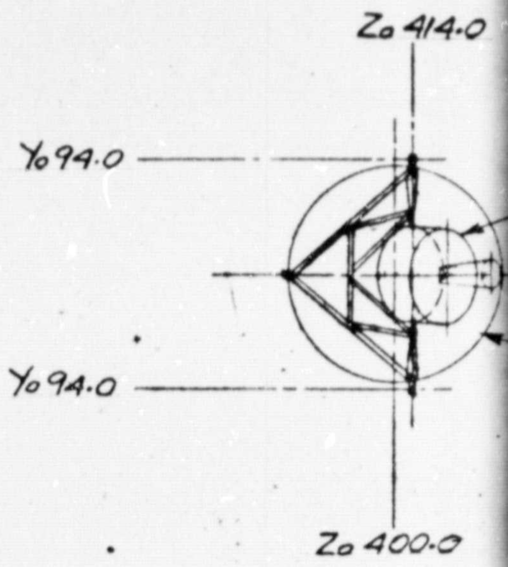


SECTION G-G



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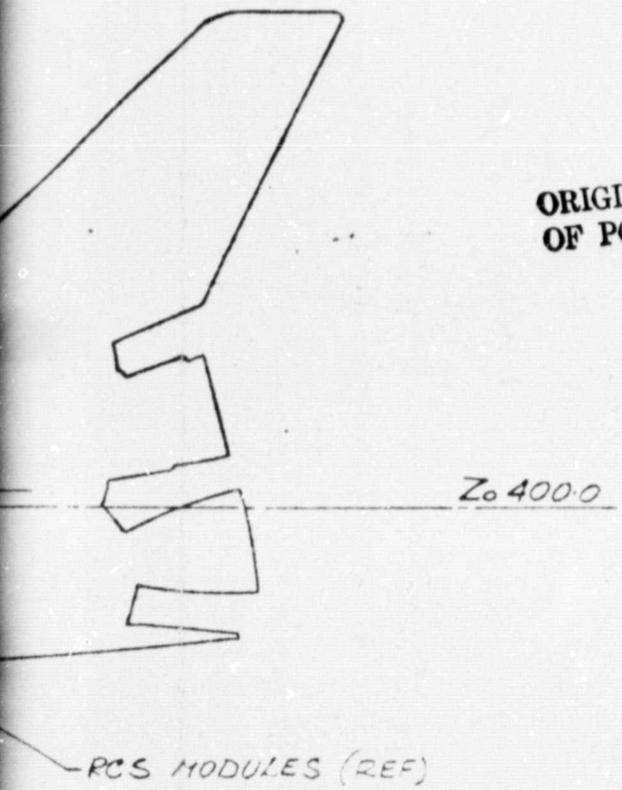

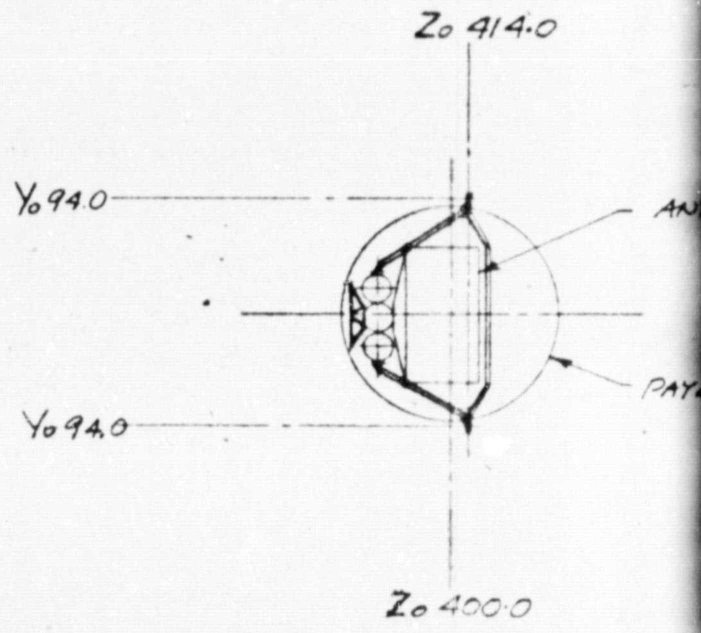

SECTION J-J

3 FOLDOUT FRAME

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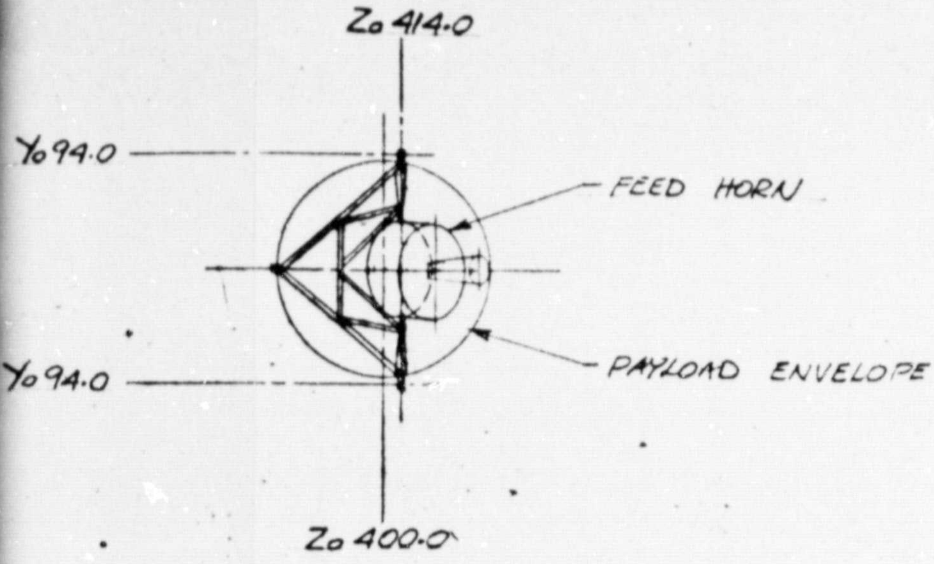
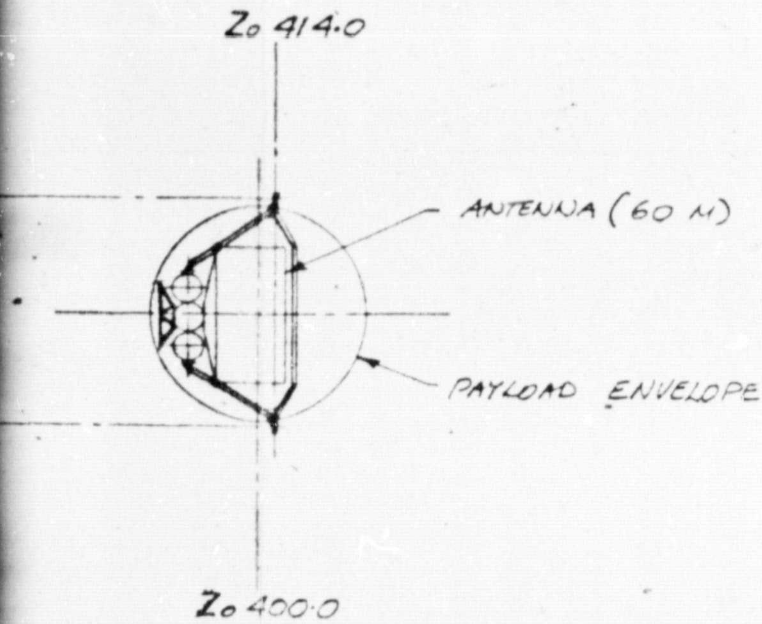


SECTION H-H



SECTION J-J

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SHT 3 OF 3
A-49, A-50

1/80		Rockwell International	
SHUTTLE BAY PACKAGING - THIRD FLIGHT			42662-68

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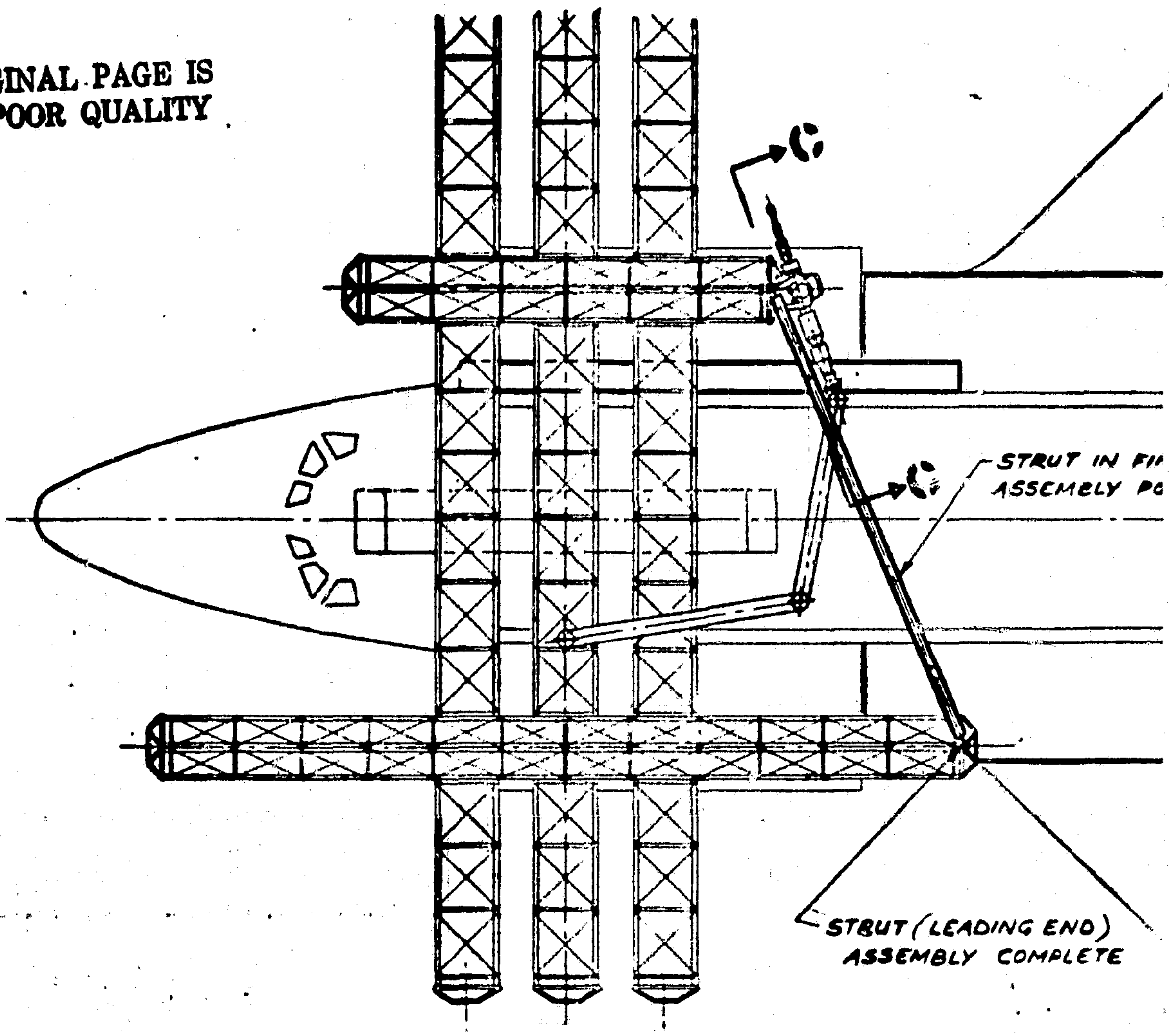
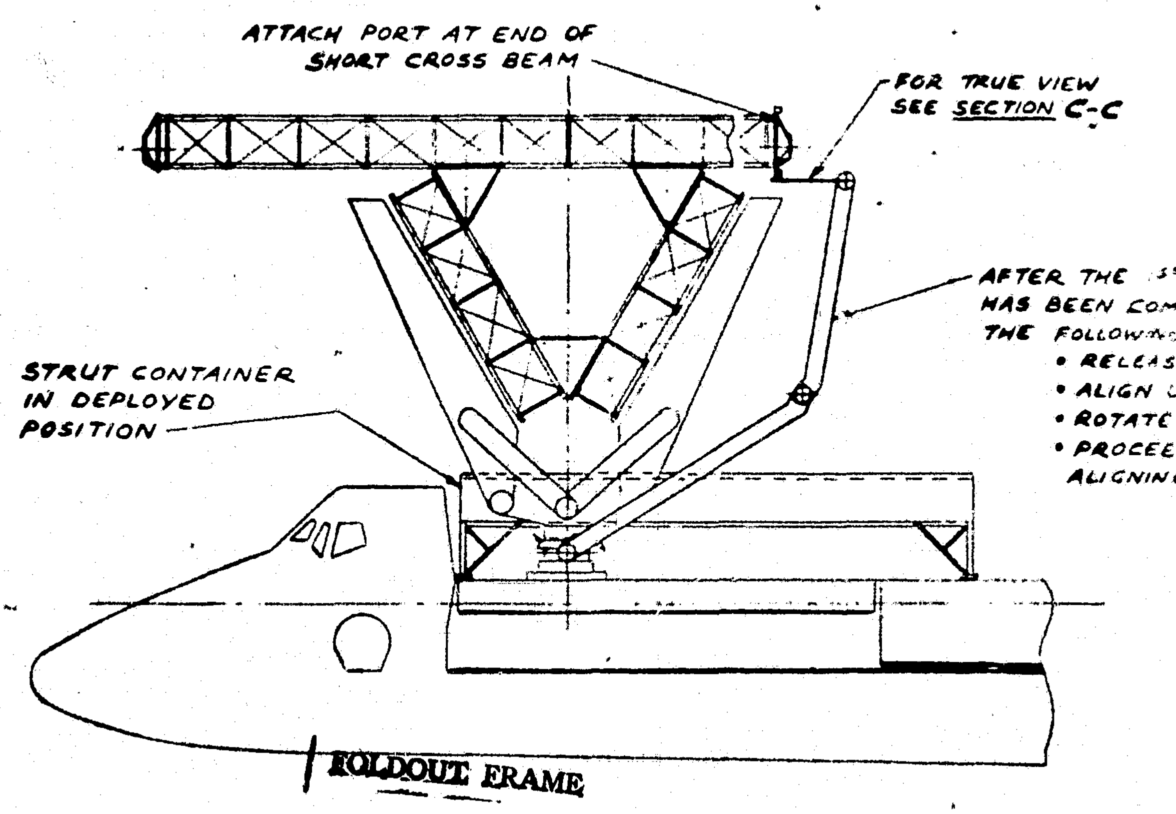
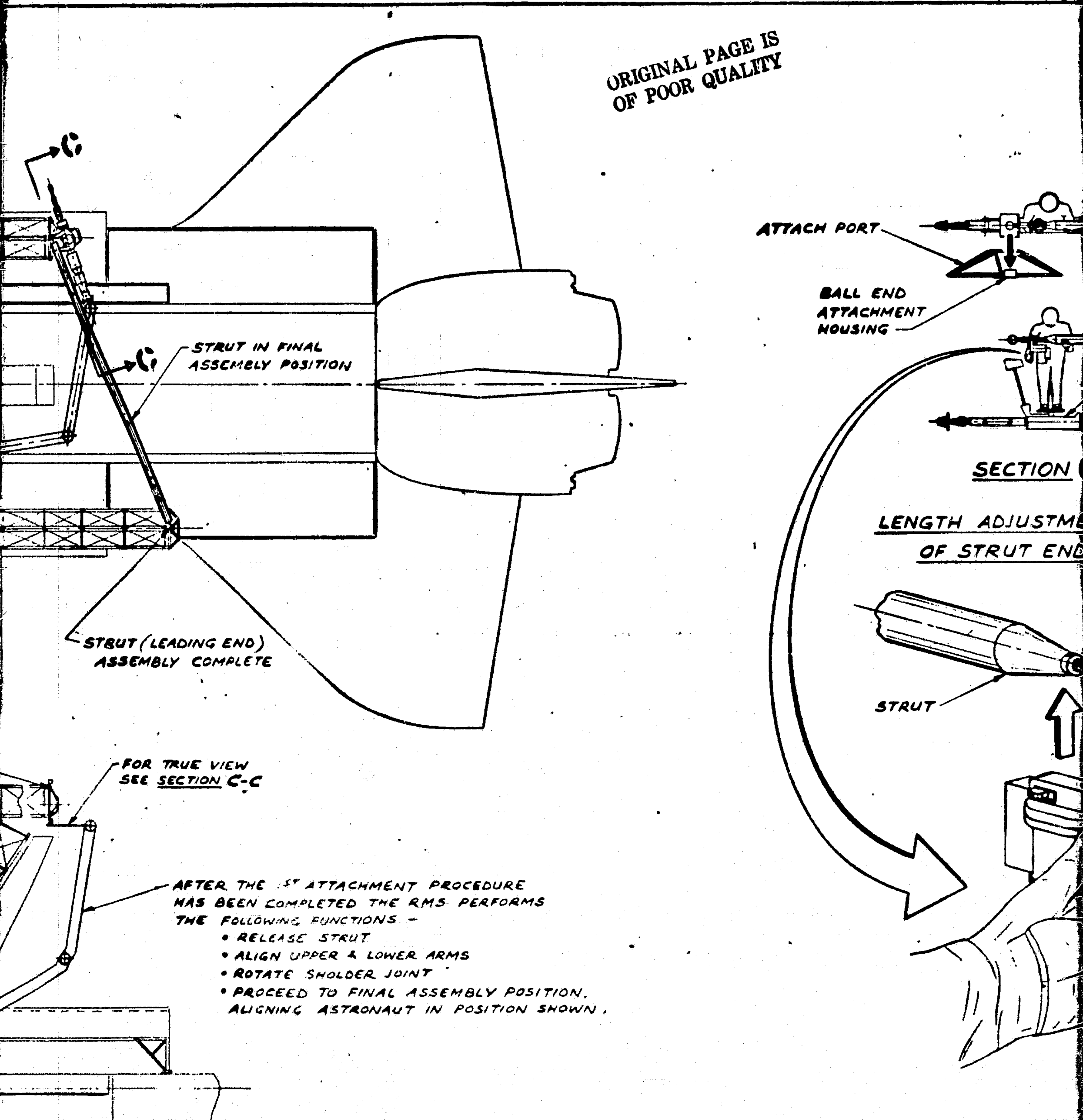
OF POOR QUALITY



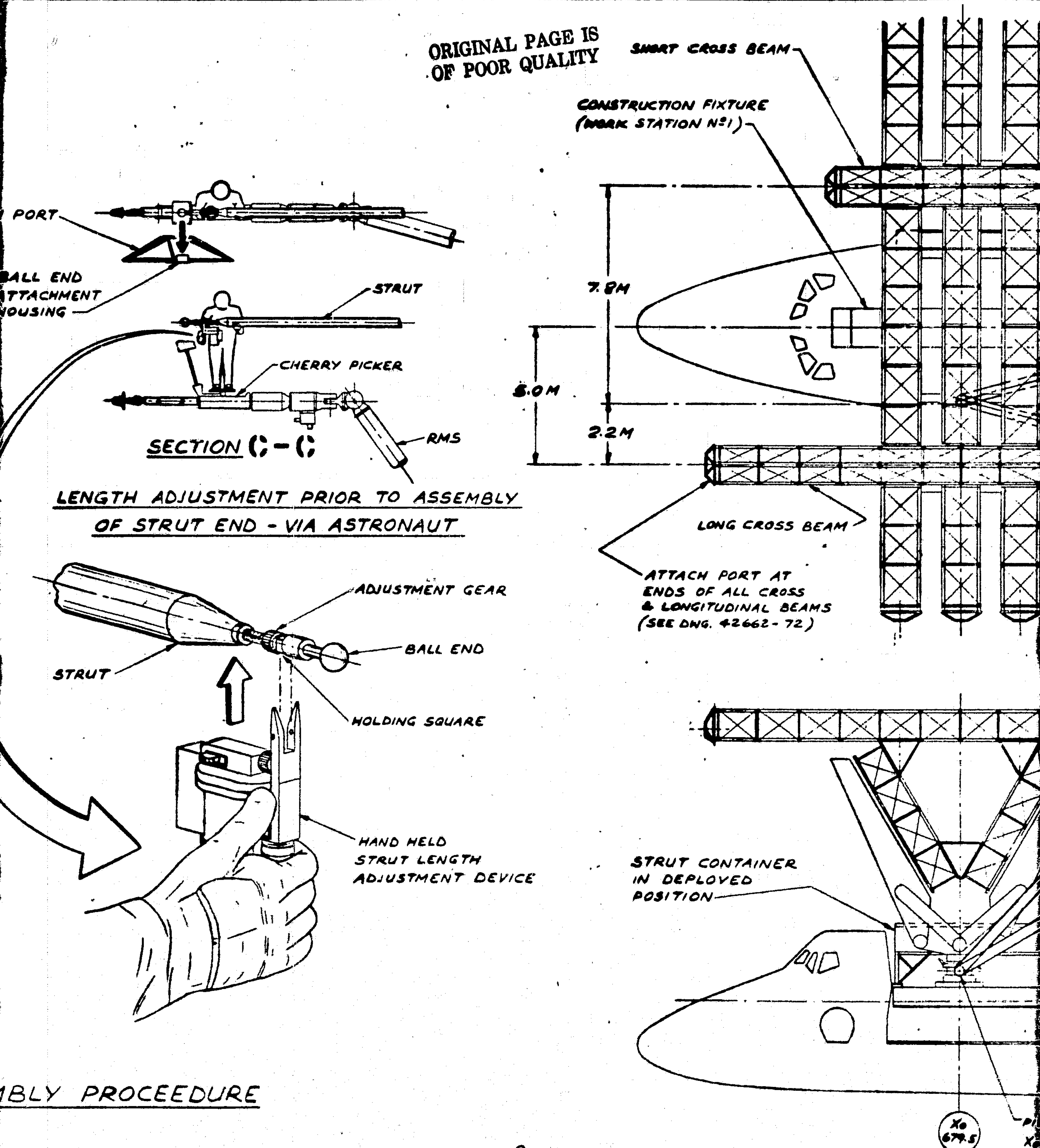


FOLDOUT FRAME

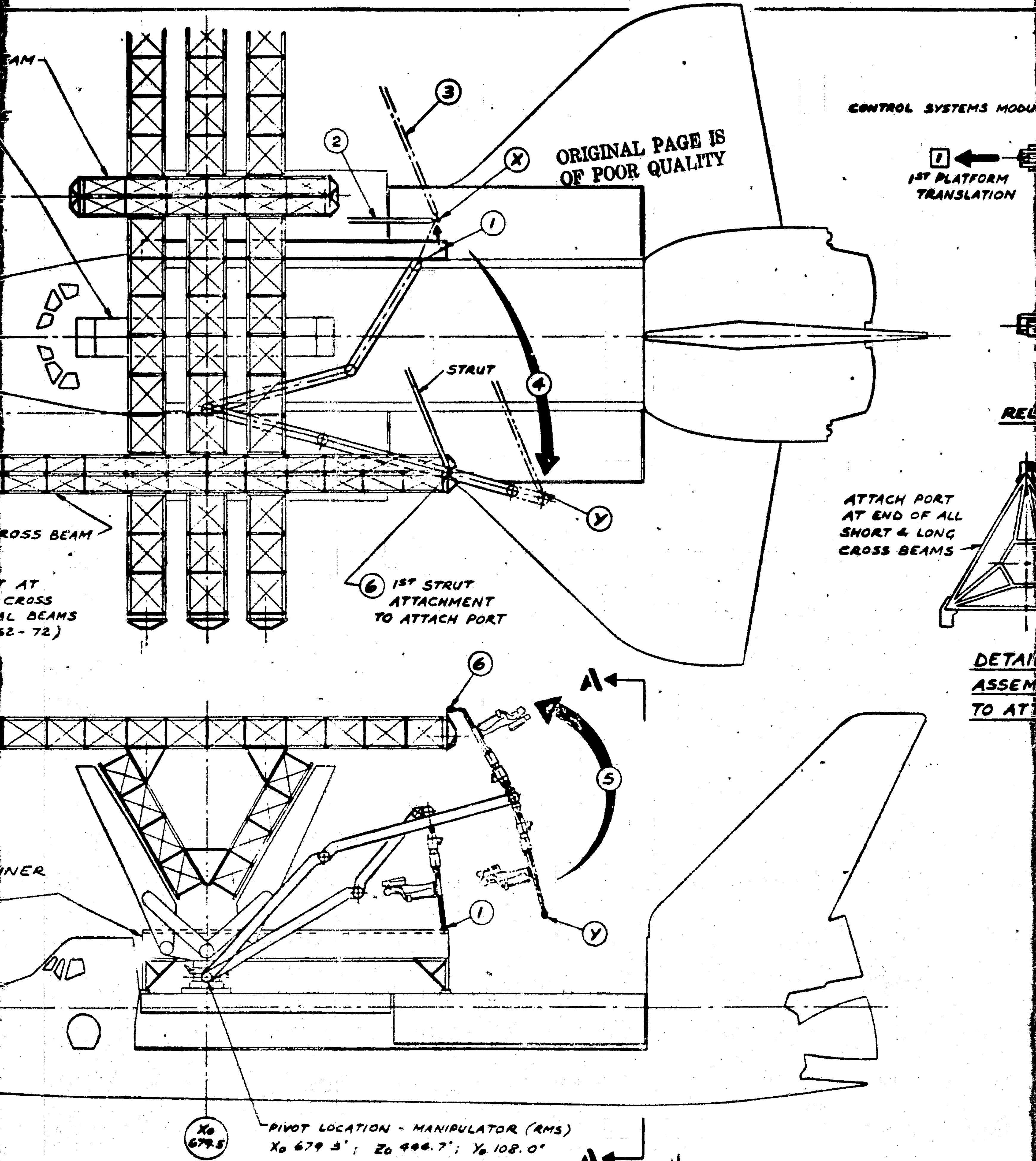


STRUT (TRAILING END) ASSEMBLY PROCEEDUR

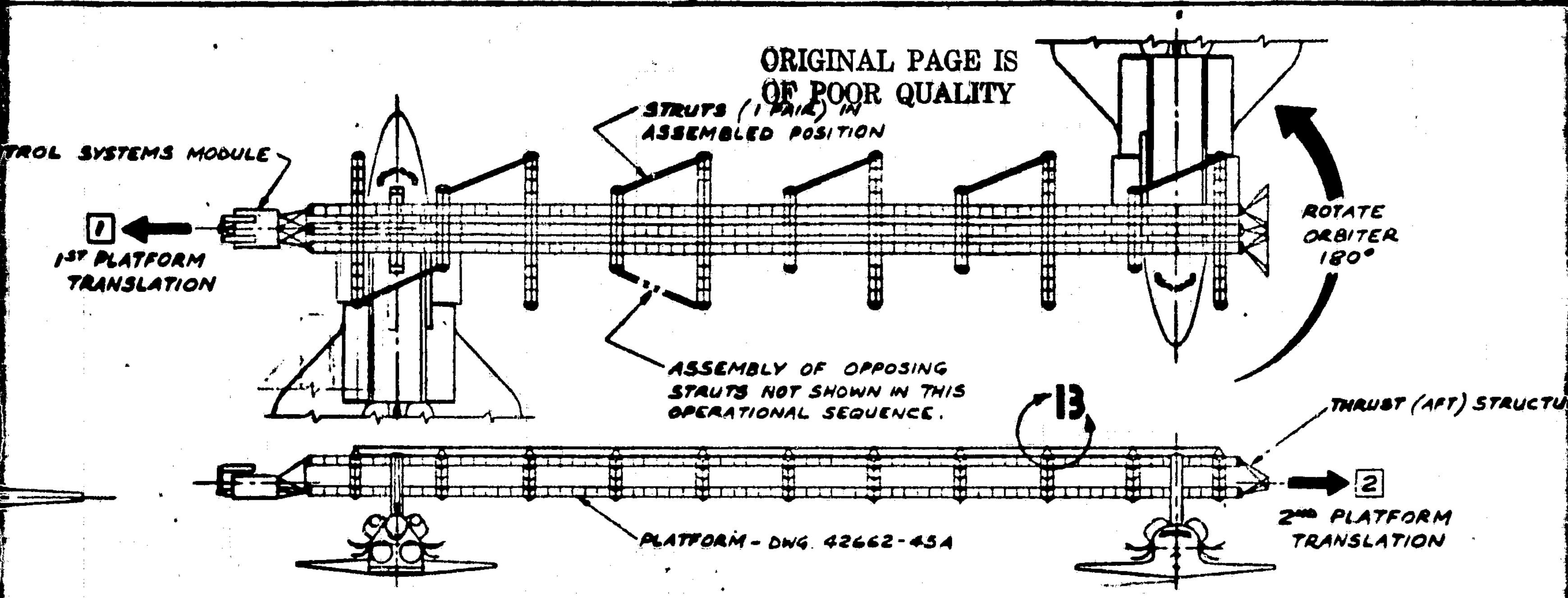
VIA ASTRONAUT



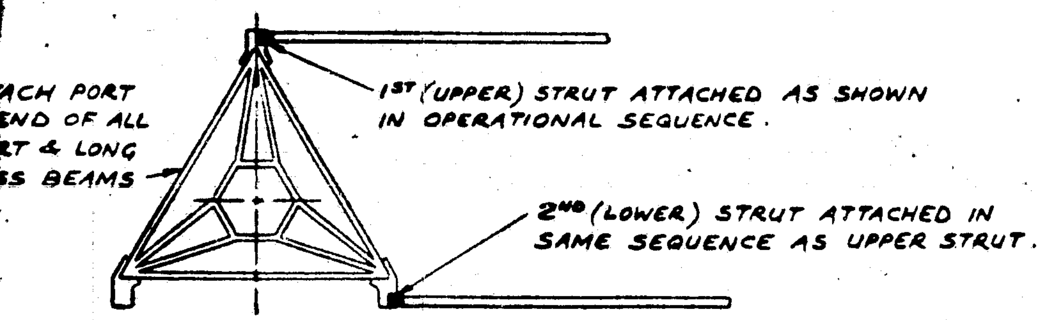
3 FOLDOUT FRAME



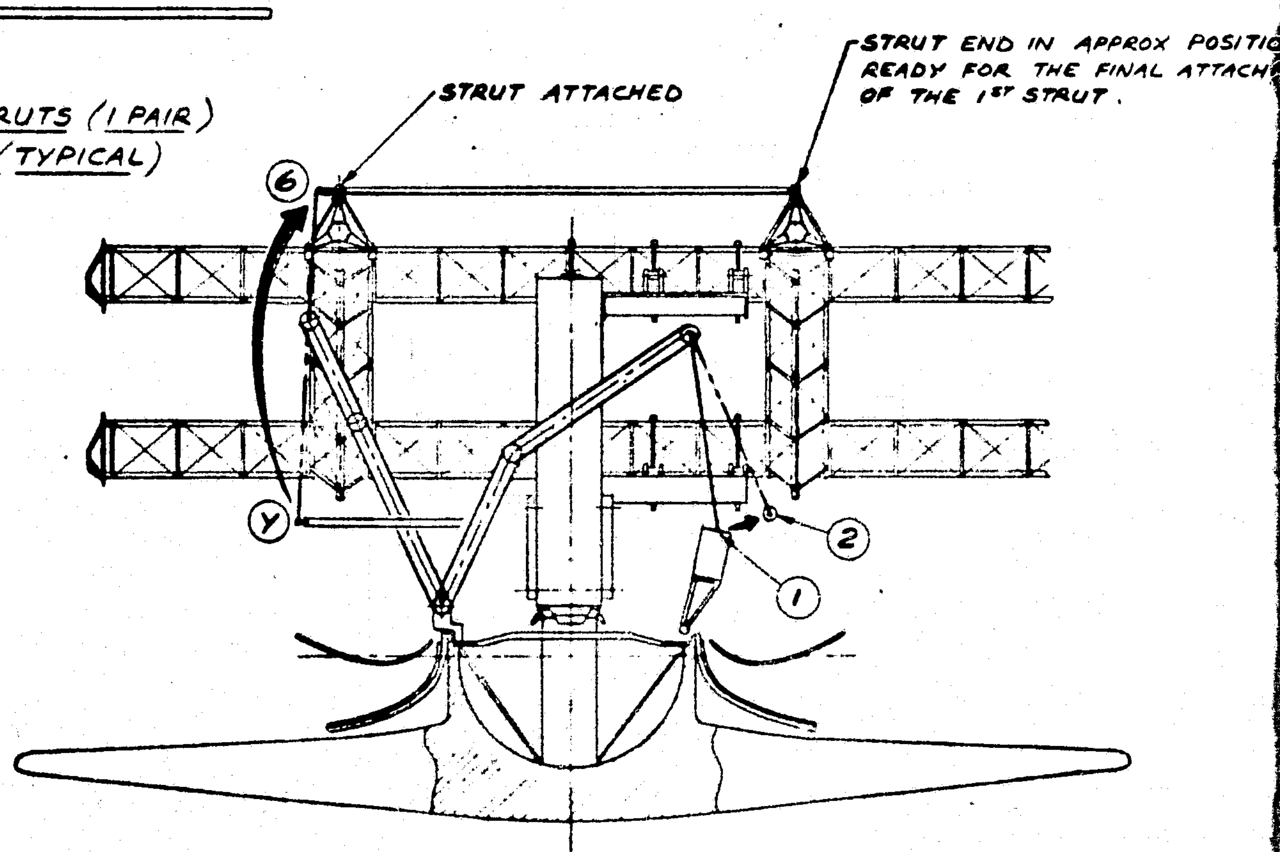
4 FOLDOUT FRAME



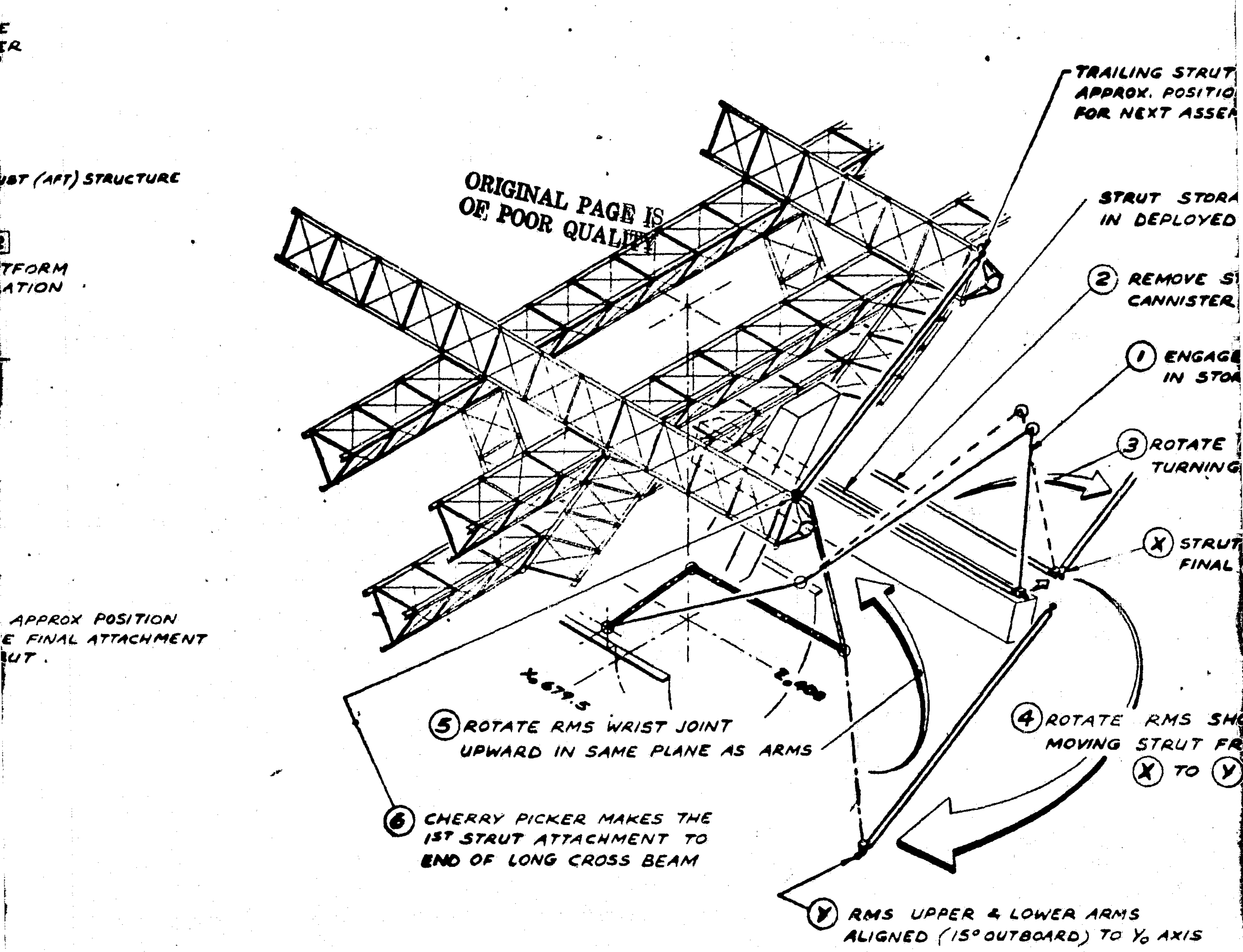
RELATIONSHIP OF ORBITER TO PLATFORM FOR STRUT ATTACHMENT AS DEPICTED



DETAIL B
ASSEMBLY OF STRUTS (1 PAIR)
TO ATTACH PORT (TYPICAL)



SECTION A - A



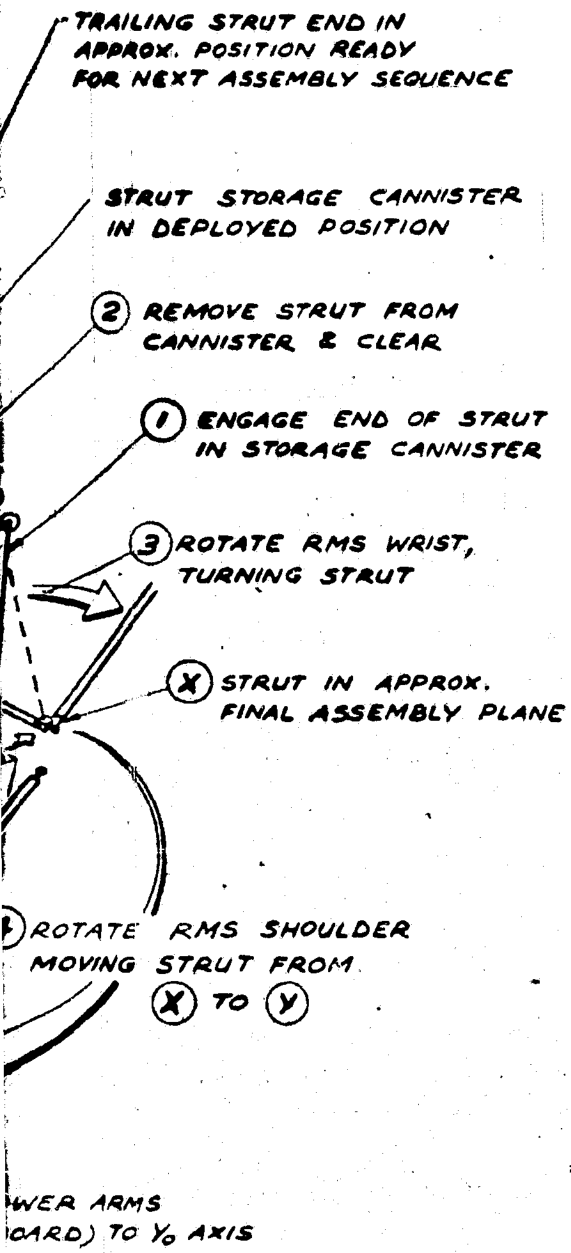
STRUT REMOVAL TO 1ST ATTACHMENT PROCEEDU

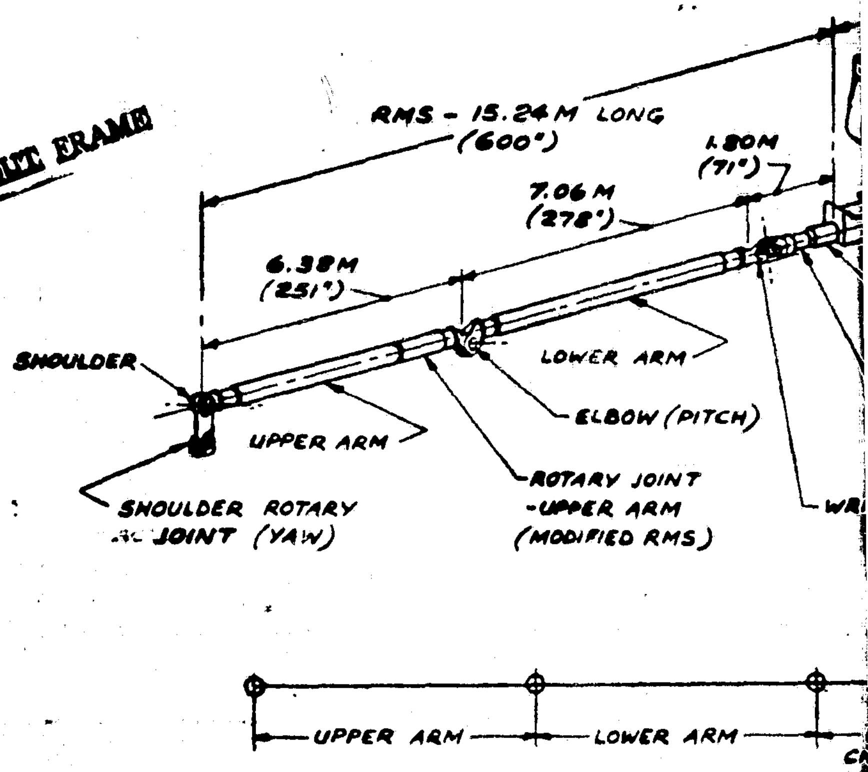
STRUT (LEADING END) ASSEMBLY ACCOMPLISHE

VIA CHERRY PICKER

6 FOLDOUT FRAME

FOLDOUT FRAME





ASSEMBLY AS DEPICTED IN PRECEEDIN

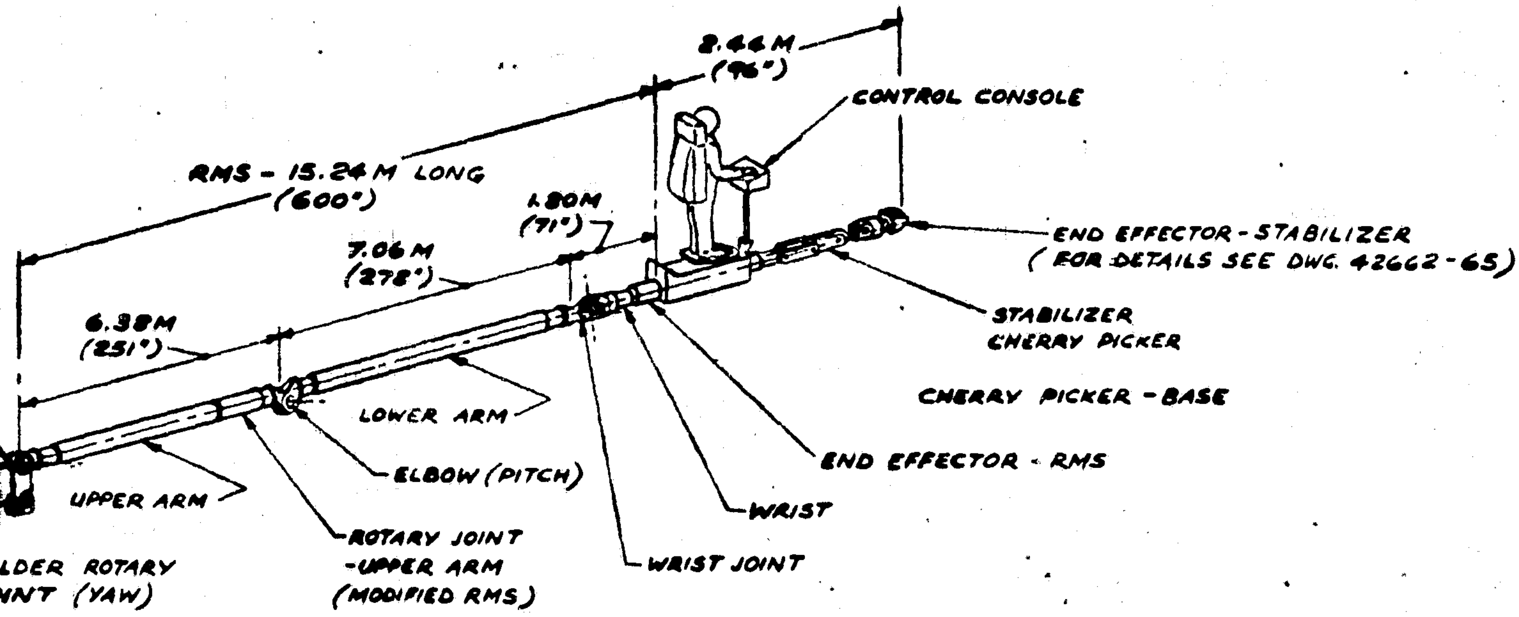
RMS/CHERRY PICKER A

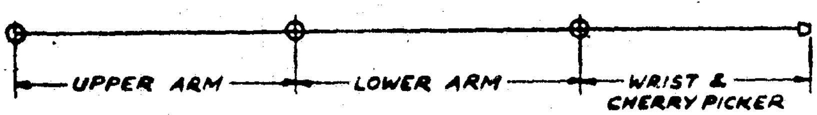
ENT PROCEEDURE.

ACCOMPLISHED

ORIGINAL PAGE
OF POOR QUALITY

FOLDOUT FRAME





ASSEMBLY AS DEPICTED IN PRECEEDING ILLUSTRATIONS.

RMS/CHERRY PICKER ASSEMBLY

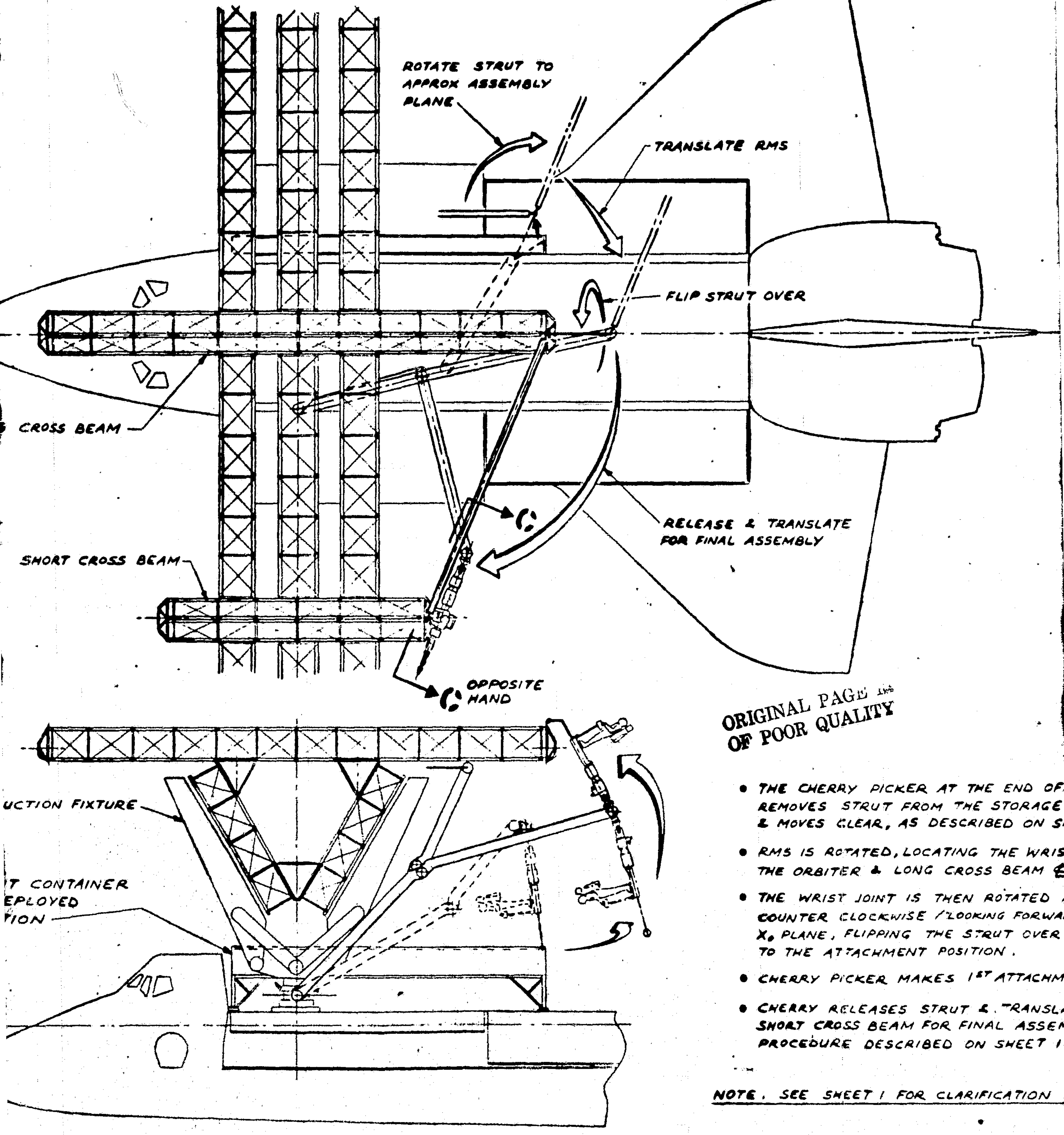
ORIGINAL PAGE IS OF POOR QUALITY

A-51,
A-52

1/80	BKK 2/5/8 SC 5A	Rockwell International	
BRACING STRUT INSTALLATION VIA., CHERRY PICKER			42662-71 SHEET 1 OF 2

ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME

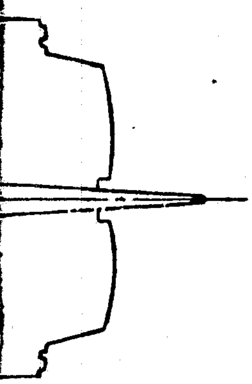


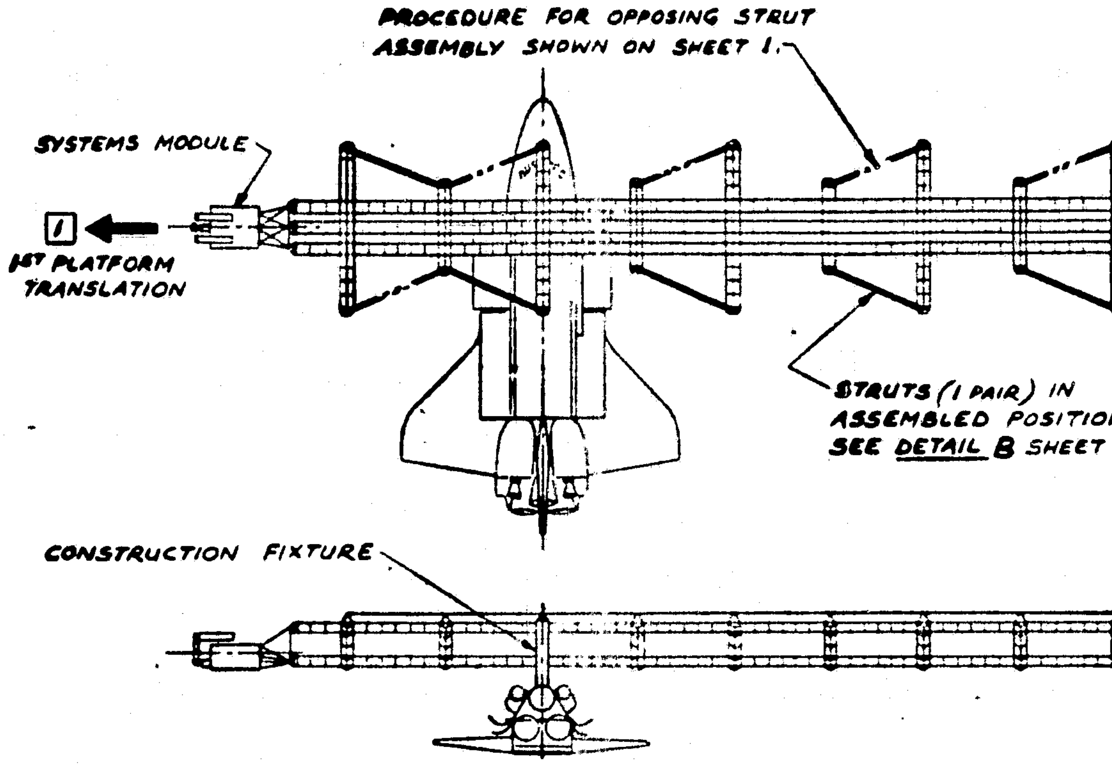
ORIGINAL PAGE IS
OF POOR QUALITY

- THE CHERRY PICKER AT THE END OF
REMOVES STRUT FROM THE STORAGE
& MOVES CLEAR, AS DESCRIBED ON S
- RMS IS ROTATED, LOCATING THE WRIS
THE ORBITER & LONG CROSS BEAM ℄
- THE WRIST JOINT IS THEN ROTATED
COUNTER CLOCKWISE (LOOKING FORWA
X_o PLANE, FLIPPING THE STRUT OVER
TO THE ATTACHMENT POSITION.
- CHERRY PICKER MAKES 1ST ATTACHM
- CHERRY RELEASES STRUT & TRANSL
SHORT CROSS BEAM FOR FINAL ASSEM
PROCEDURE DESCRIBED ON SHEET 1

NOTE. SEE SHEET 1 FOR CLARIFICATION

2 FOLDOUT FRAME





RELATIONSHIP OF ORBITER TO PLATFORM FOR STRUT ATT

NOTE: • PLATFORM IS TRANSLATED THRU CONSTRUCTION FI & ALL STRUTS (SHEET 1 & SHEET 2) ARE ASSEMBL SIDE OF PLATFORM CLOSEST TO AFT END OF ORBITE

• ORBITER IS ROTATED & PROCEDURE REPEATED

R AT THE END OF THE RMS ROM THE STORAGE CANNISTER S DESCRIBED ON SHEET 1.

OCATING THE WRIST ABOVE NG CROSS BEAM ℄.

S THEN ROTATED APPROX 180° E (LOOKING FORWARD) IN THE THE STRUT OVER ADJACENT T POSITION.

AKES 1ST ATTACHMENT (SEE SHEET 1)

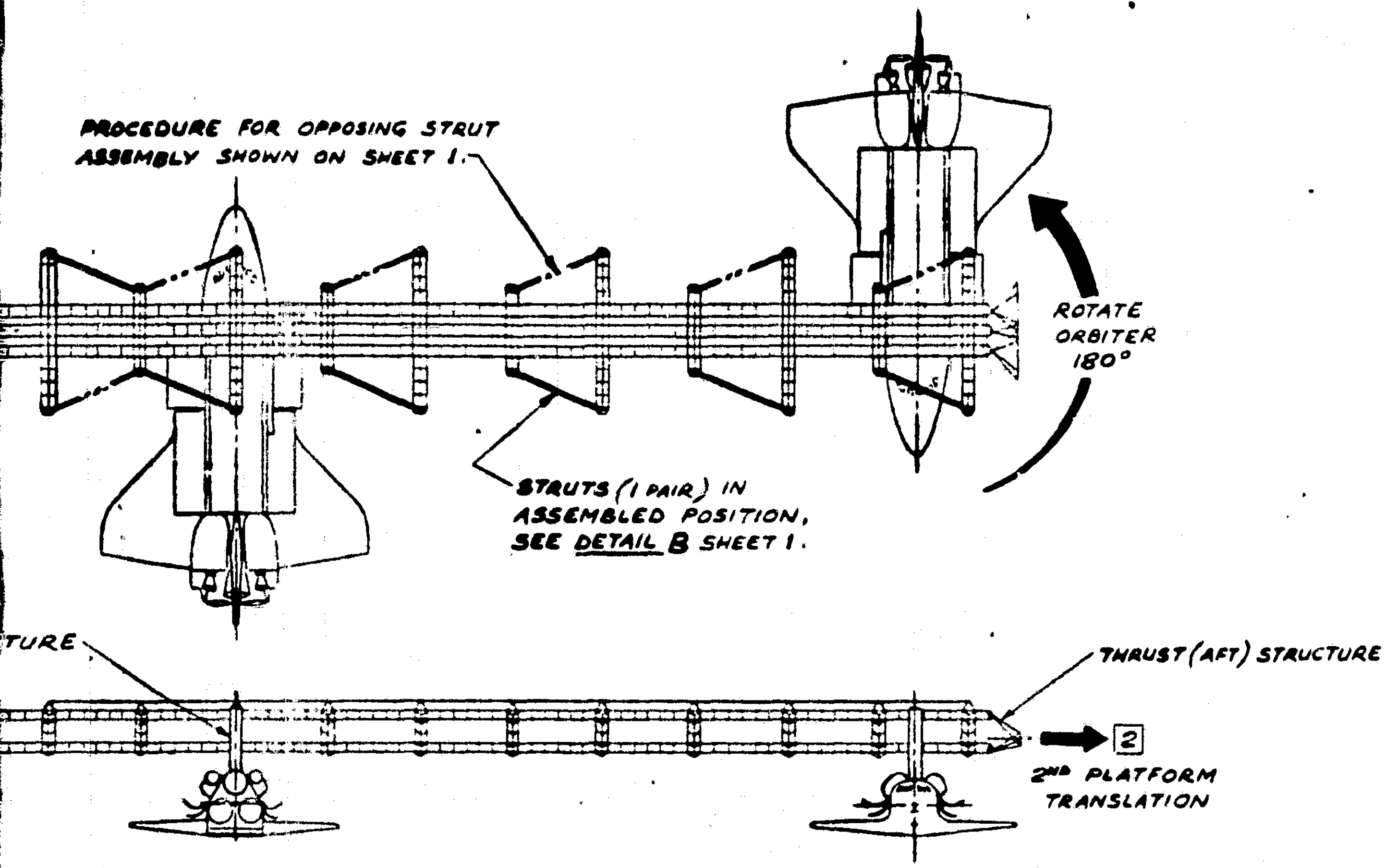
STRUT & TRANSLATES TOWARDS FOR FINAL ASSEMBLY, AS PER IBED ON SHEET 1.

R CLARIFICATION OF DETAILS ETC.

STRUT REMOVAL TO FINAL ATTACHMENT

SCALE 1/80	
BRA	

3 FOLDOUT FRAME



NSHIP OF ORBITER TO PLATFORM FOR STRUT ATTACHMENT AS DEPICTED.

TE: • PLATFORM IS TRANSLATED THRU CONSTRUCTION FIXTURE & ALL STRUTS (SHEET 1 & SHEET 2) ARE ASSEMBLED ON SIDE OF PLATFORM CLOSEST TO AFT END OF ORBITER:

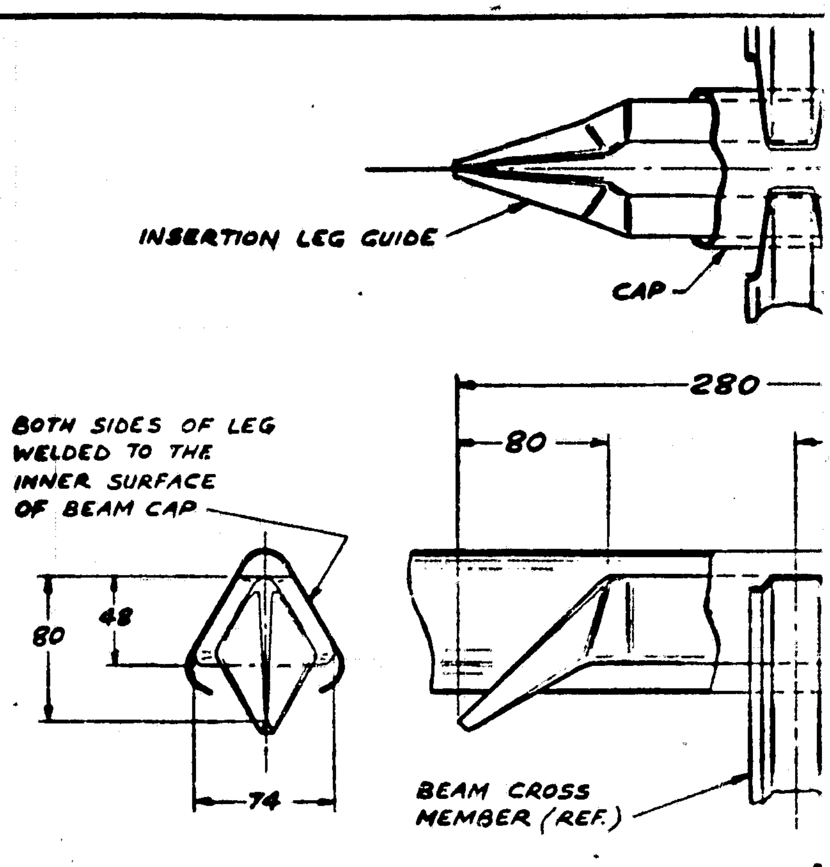
• ORBITER IS ROTATED & PROCEDURE REPEATED

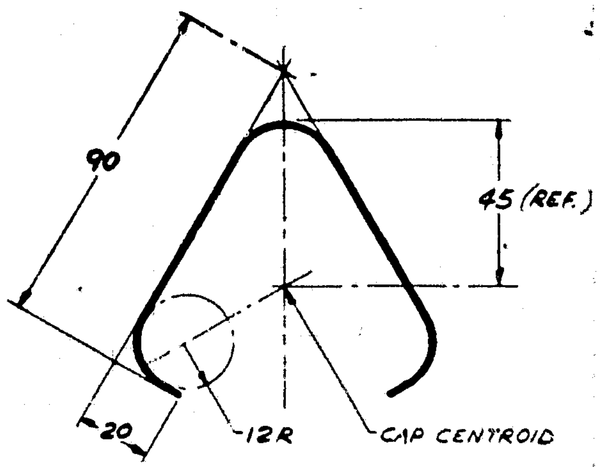
REMOVAL TO FINAL ATTACHMENT PROCEDURE

A-53,
A-54

FOLDOUT FRAME

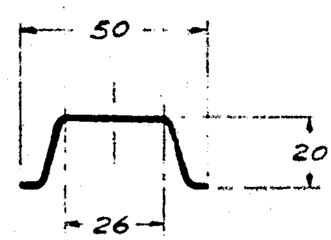
SCALE 1/80	DR BUCK DATE 2/5/ 81 MODEL SCSA	Rockwell International	
	BRACING STRUT INSTALLATION VIA., CHERRY PICKER		42662-71 SHEET 2 OF 2





DETAIL C CAP SECTION

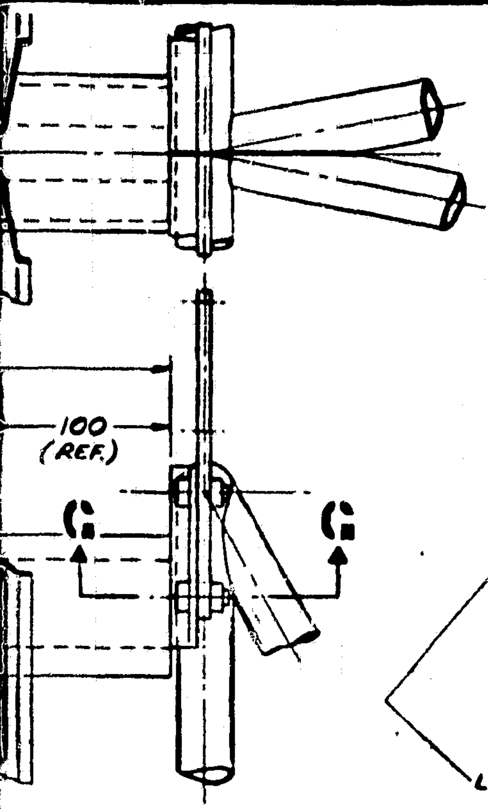
SCALE : FULL



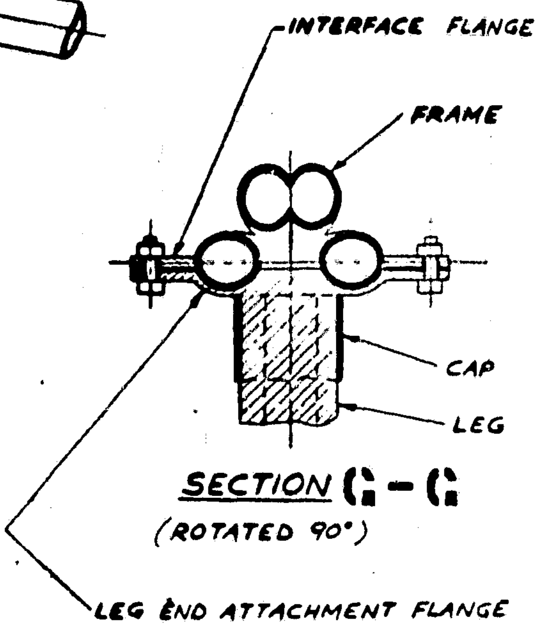
DETAIL B CROSS MEME

SCALE FULL

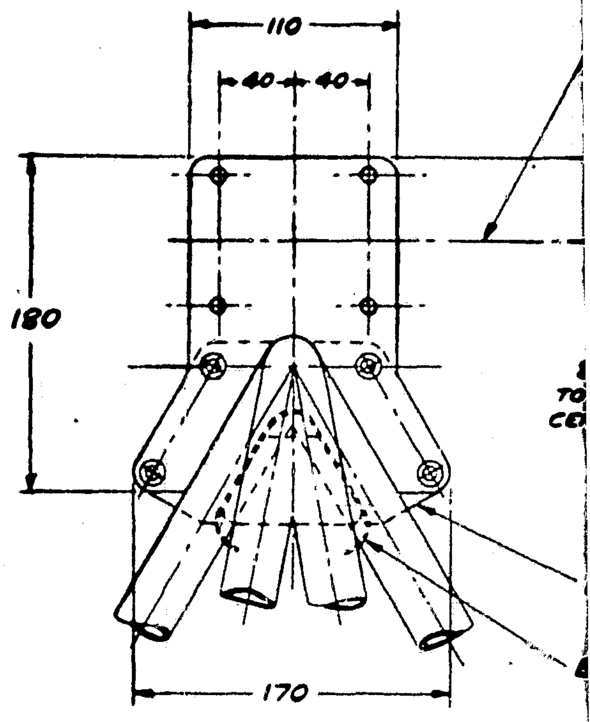
FOLDOUT FRAME



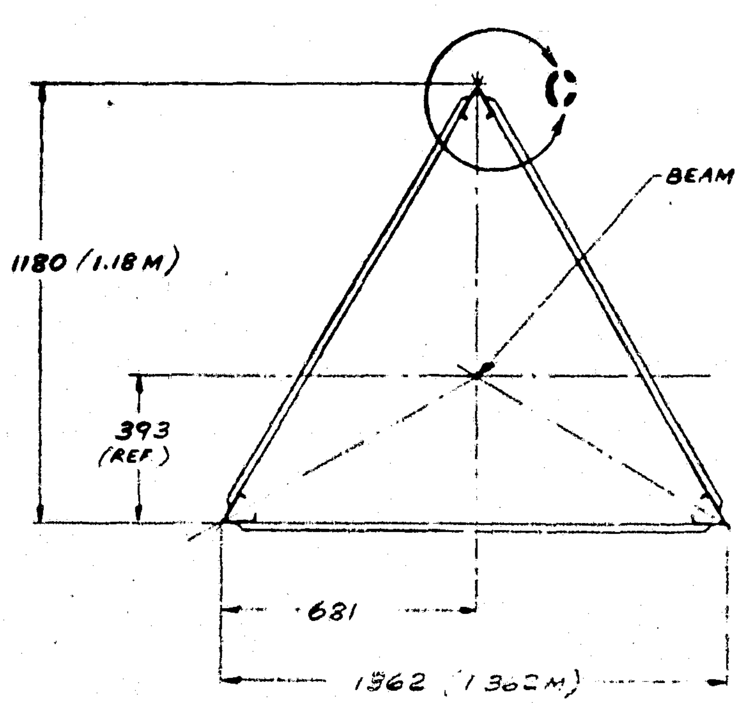
DETAIL A
SCALE: 1/2



SECTION G - G
(ROTATED 90°)

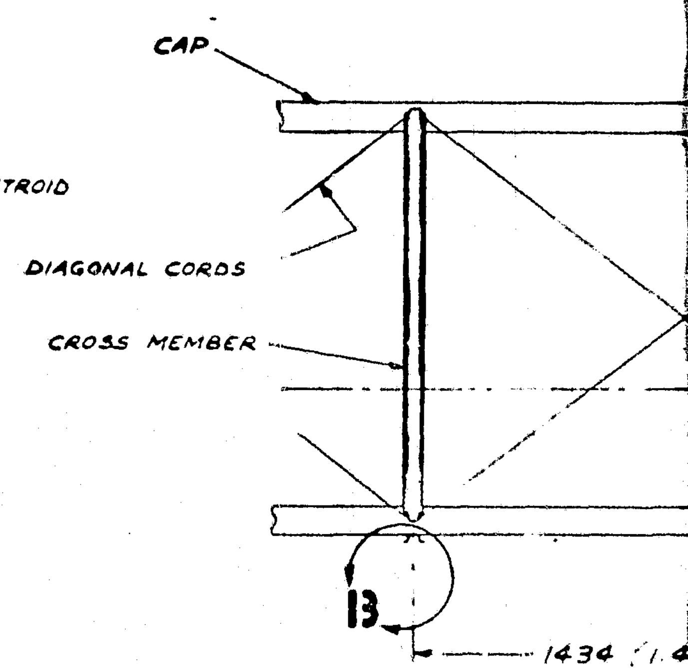


DETAIL B
SCALE: 1/2



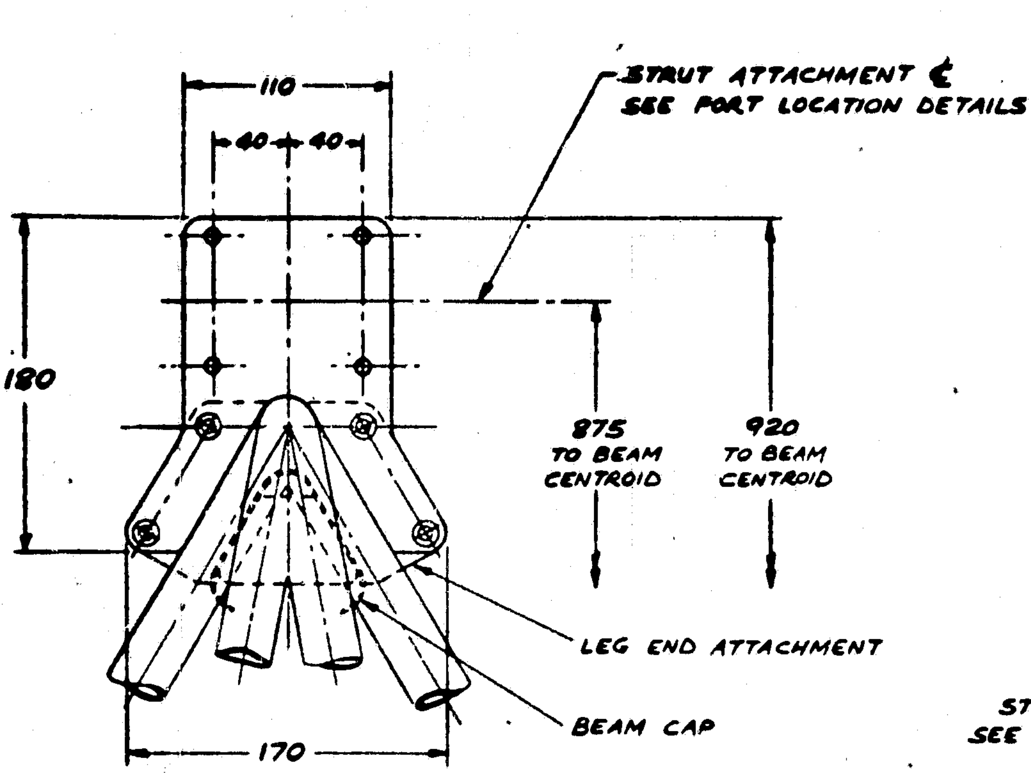
ER

BEAM GEOMETRY

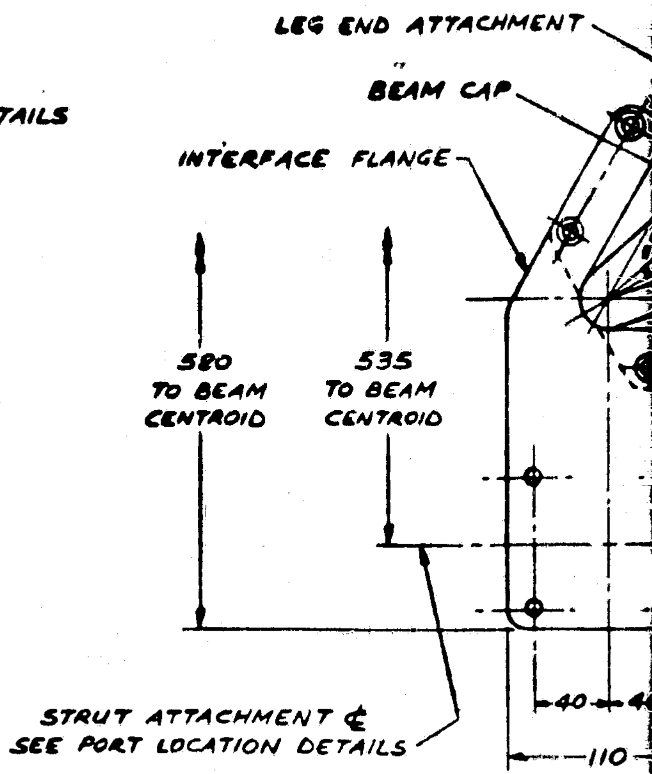


ATTACH PORT ASS

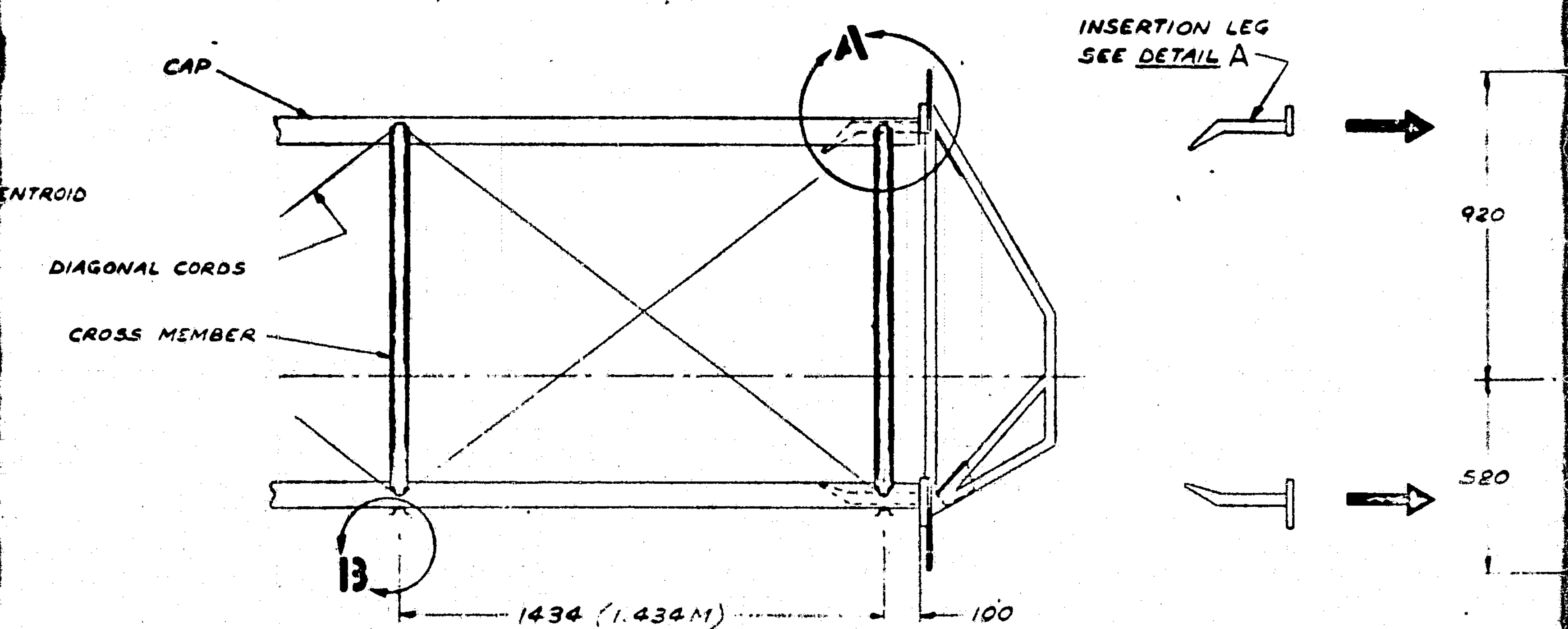
SCAL



DETAIL D
SCALE: 1/2



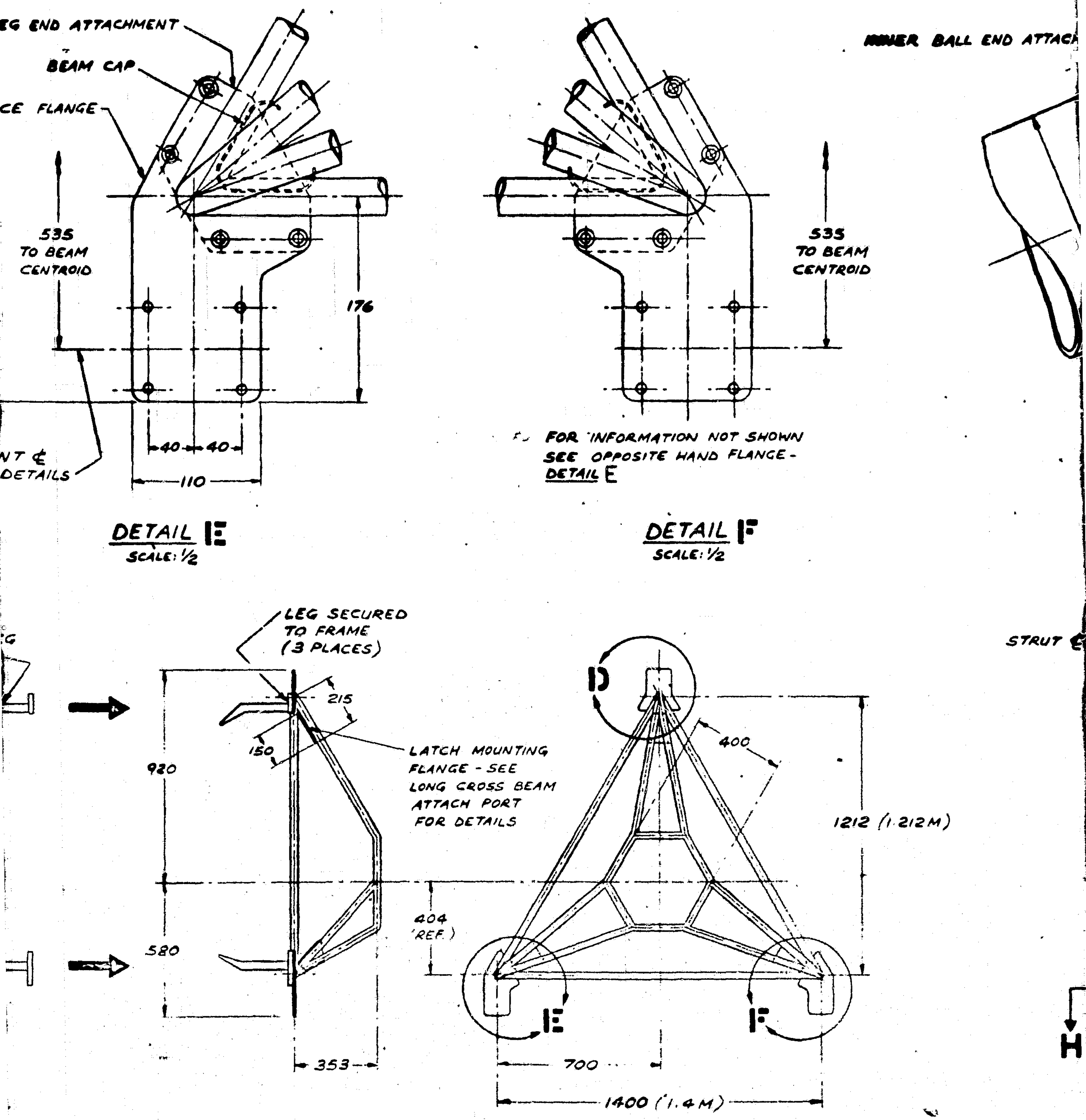
DETAIL
SCALE: 1/2



ATTACH PORT ASSEMBLED TO BEAM END

SCALE 1/10

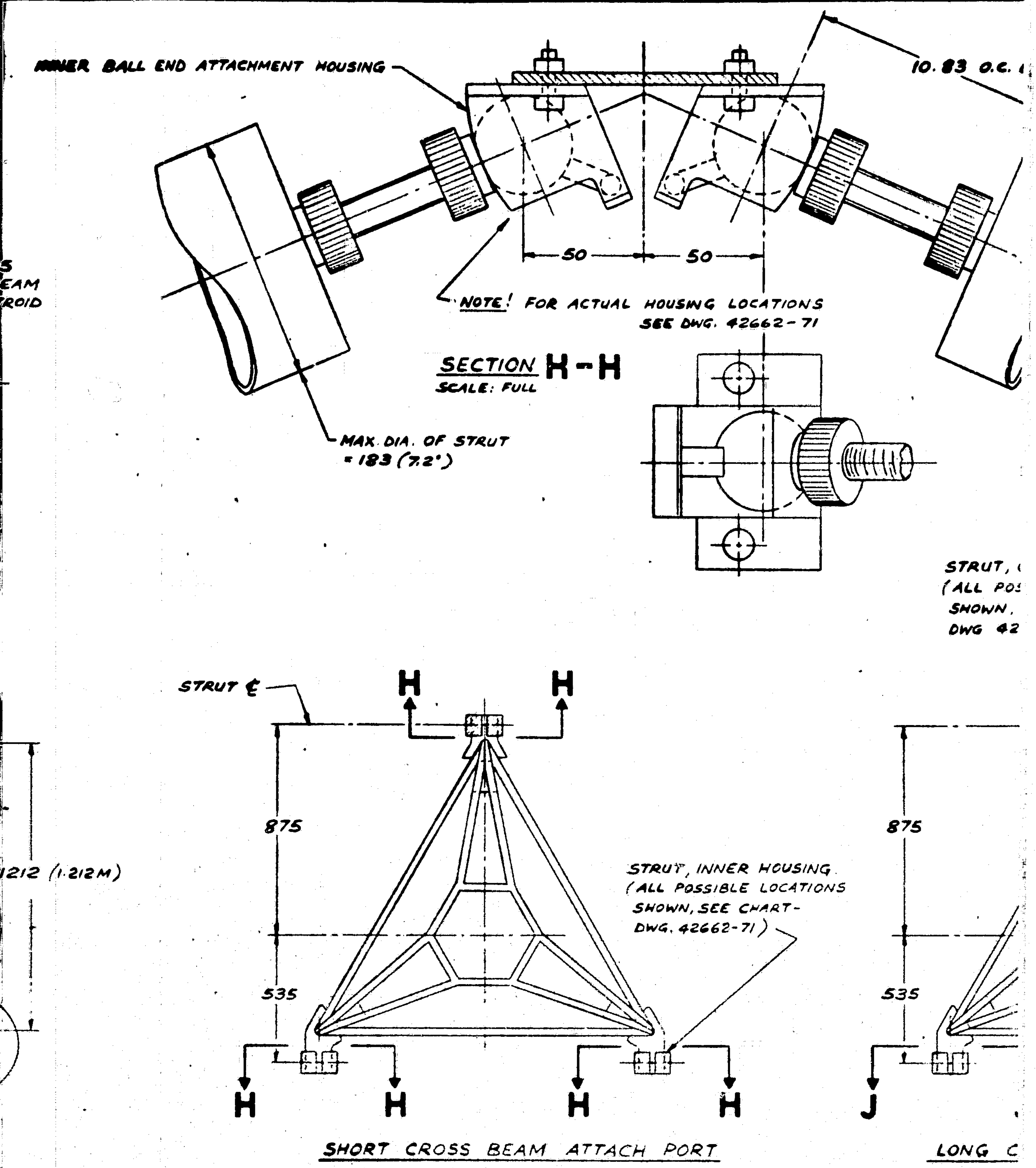
3 FOLDOUT FRAME



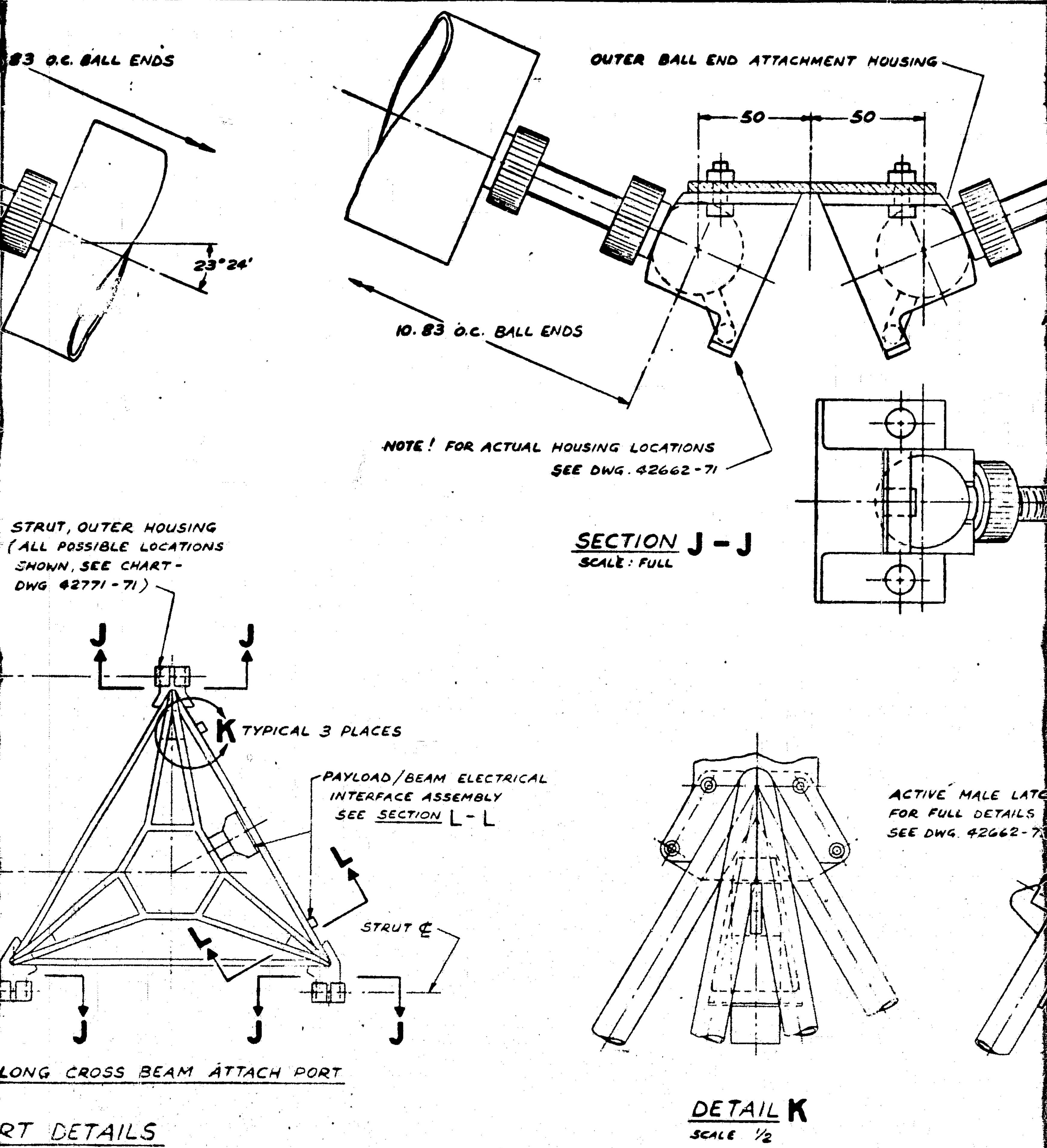
ATTACH PORT TRUSS ASSEMBLY

(IDENTICAL FOR ALL PORTS)

FOLDOUT FRAME

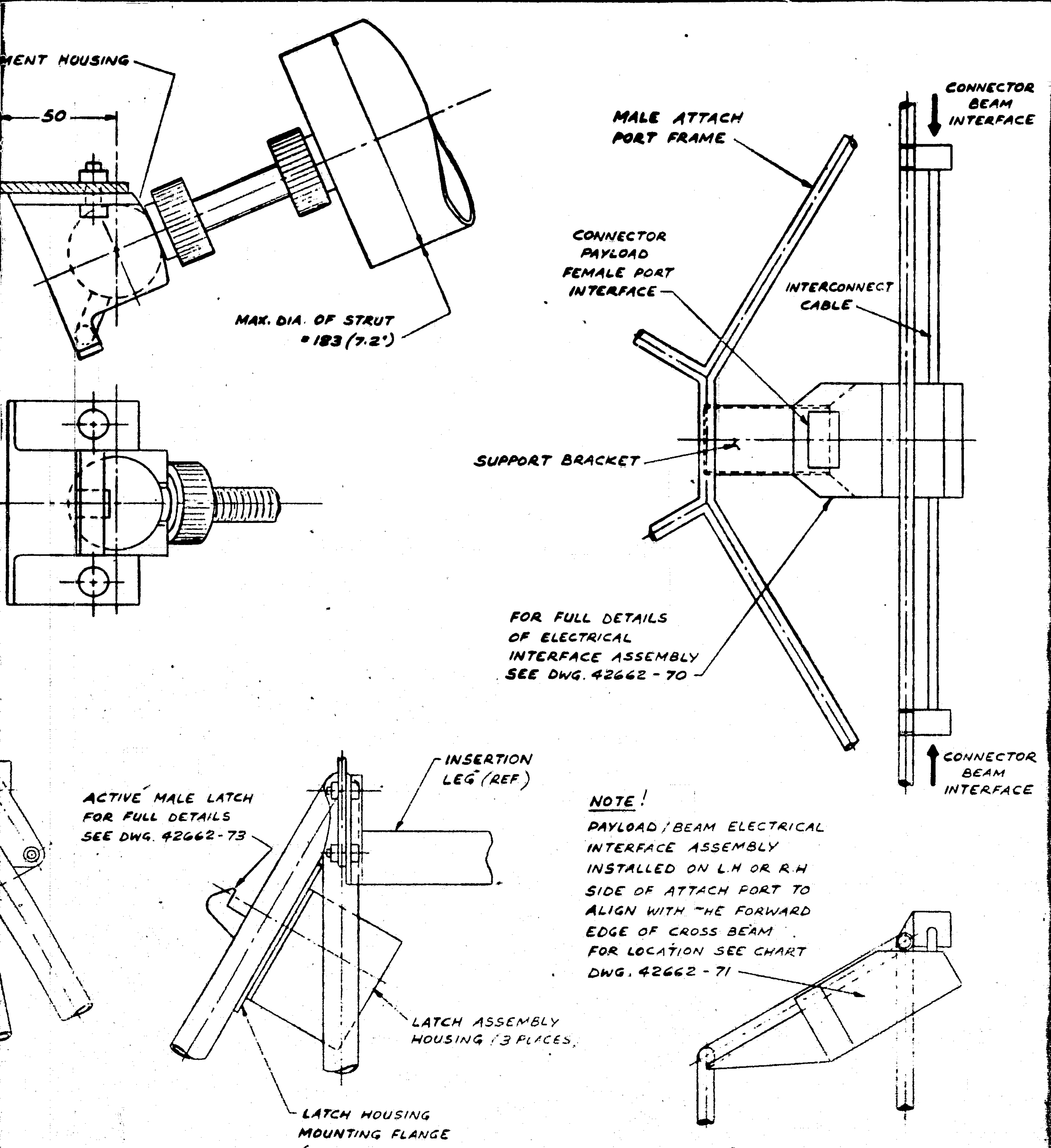


CROSS BEAM END PORT DE



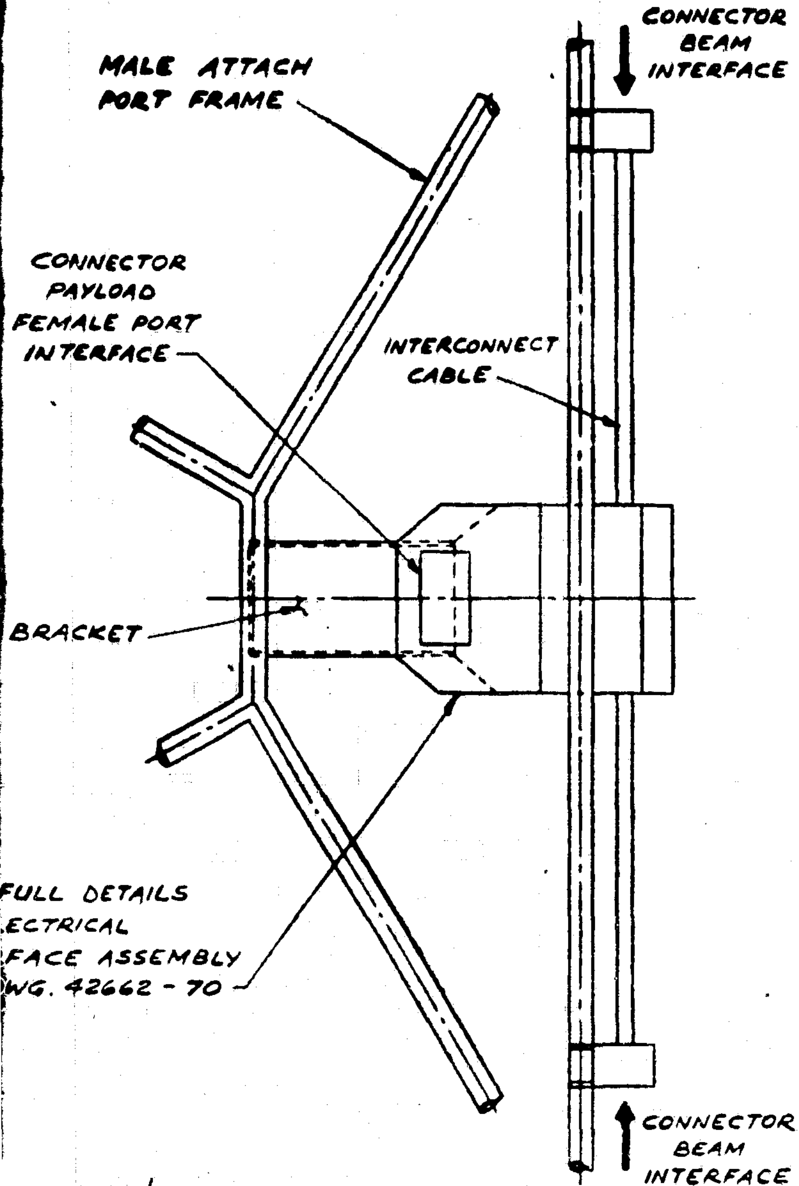
6

FOLDOUT FRAME

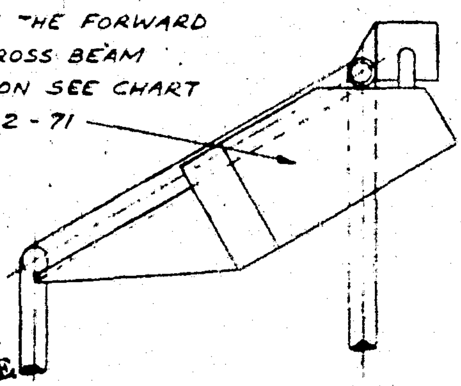


SECTION L - L
SCALE 1/4

FOLDOUT FRAME



NOTE!
PAYLOAD / BEAM ELECTRICAL INTERFACE ASSEMBLY INSTALLED ON L.H OR R.H SIDE OF ATTACH PORT TO ALIGN WITH THE FORWARD EDGE OF CROSS BEAM. FOR LOCATION SEE CHART DWG. 42662 - 71



FOLDOUT FRAME

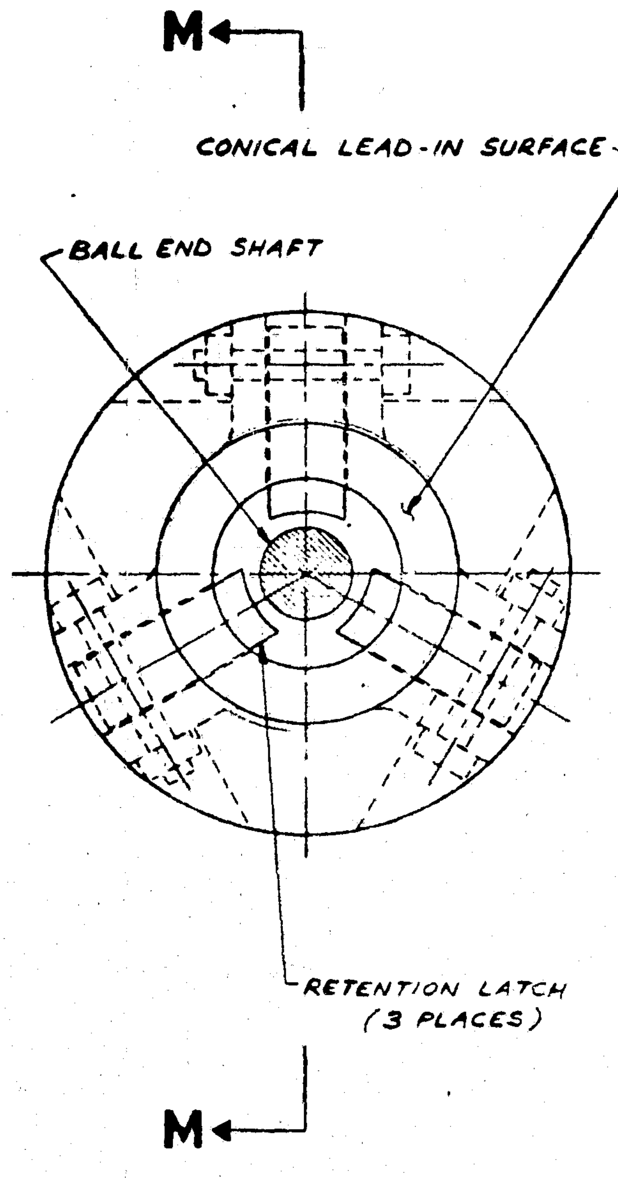
SECTION L - L
SCALE · 1/4

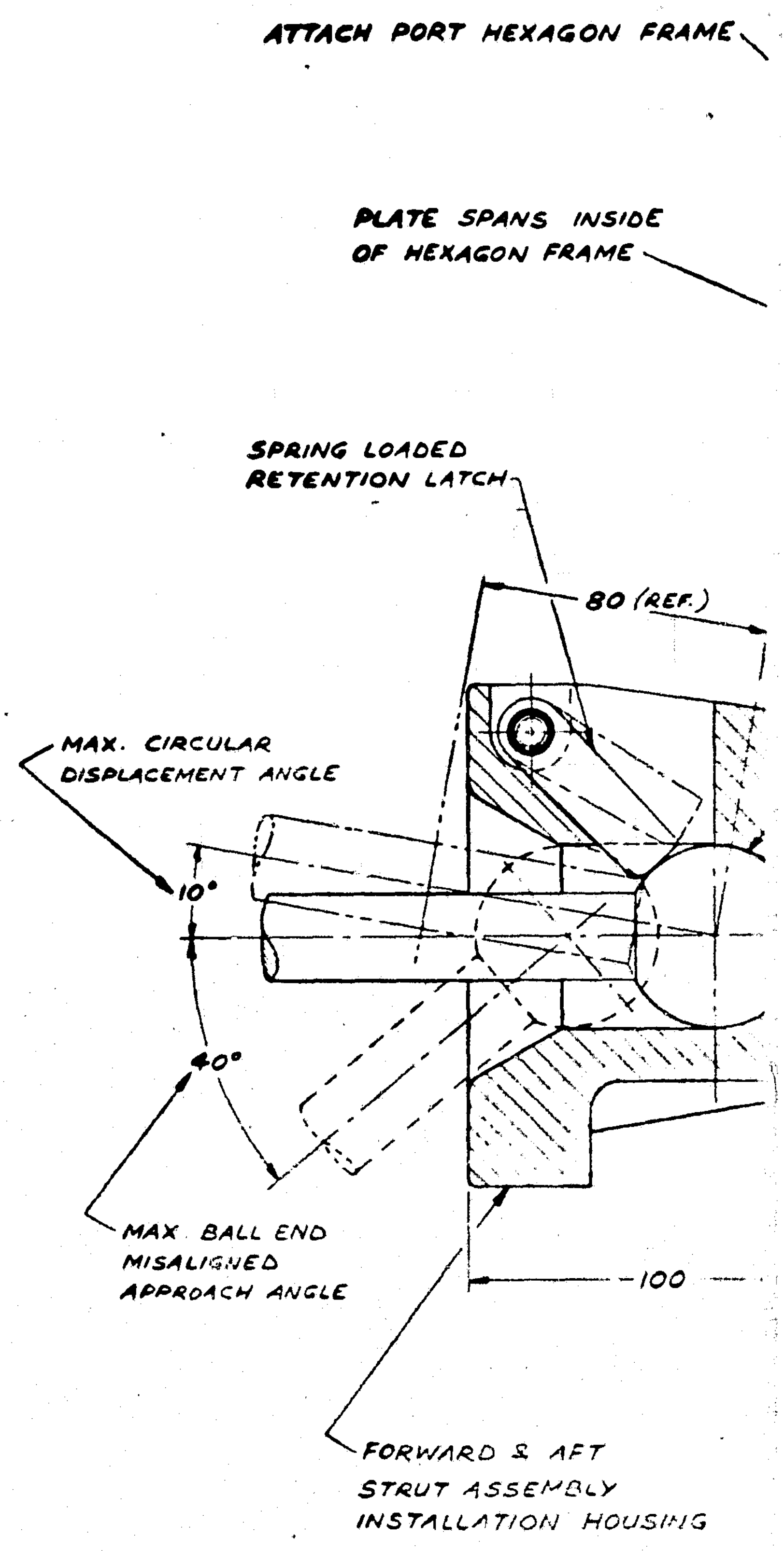
A-55,
A-56

Buck
SCSA
Rockwell International

MALE MODULE
ATTACH PORT

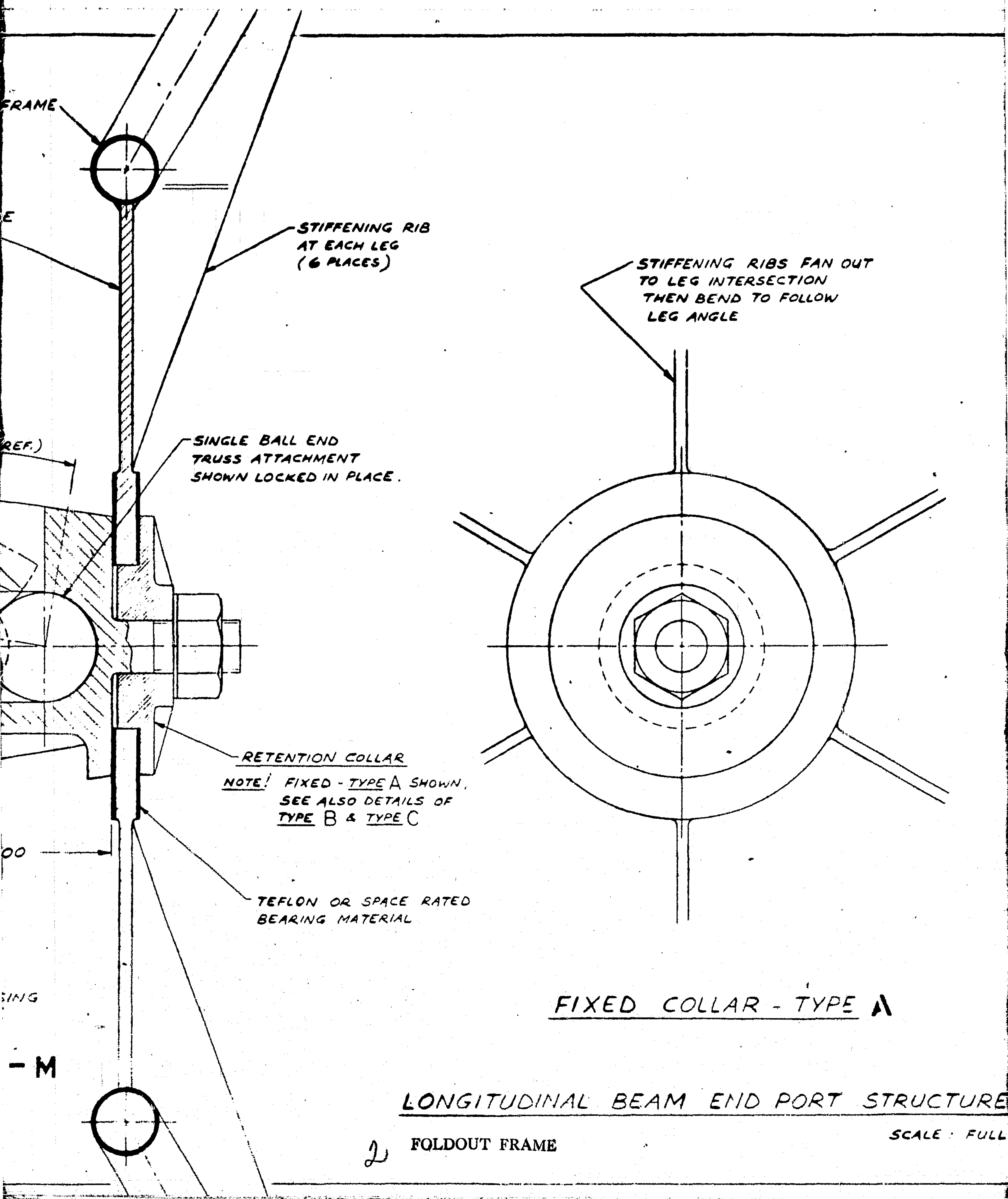
42662-72
SHEET 1 OF 2





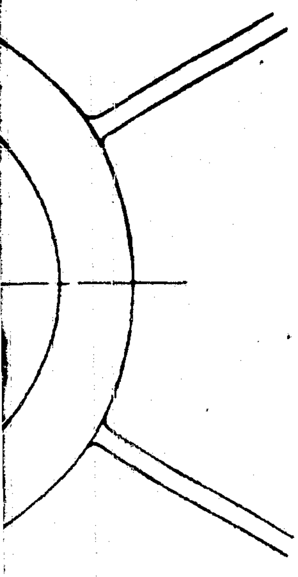
SECTION M – M

FOLDOUT FRAME

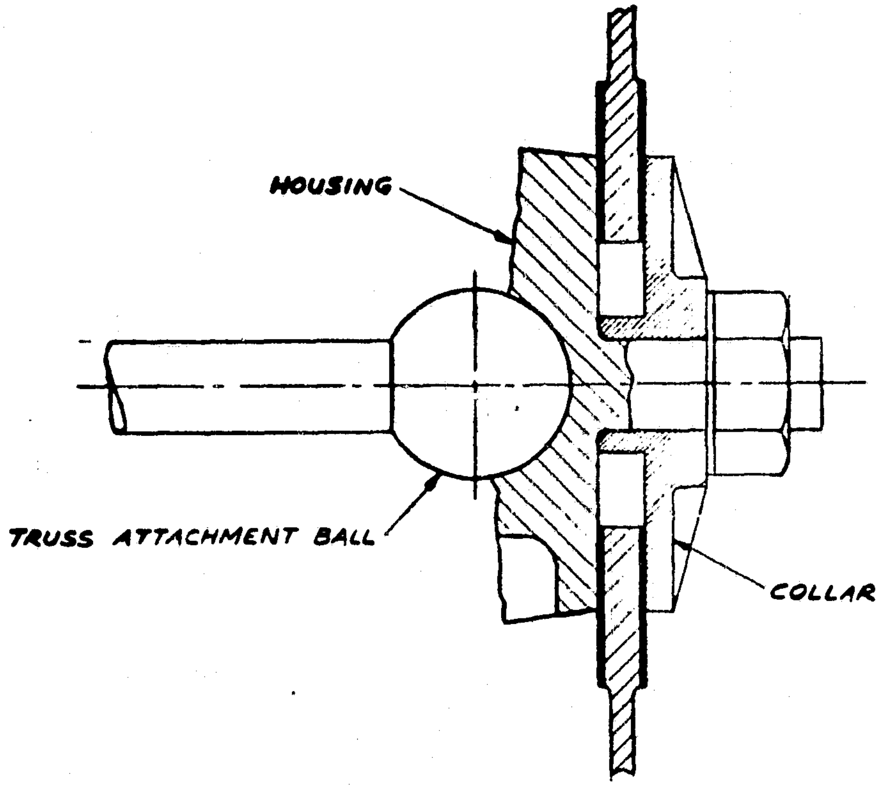


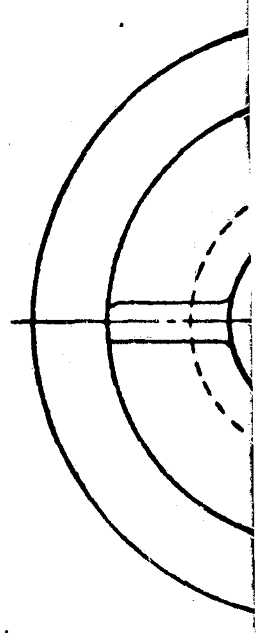
2 FOLDOUT FRAME

FAN OUT
TION
FOLLOW

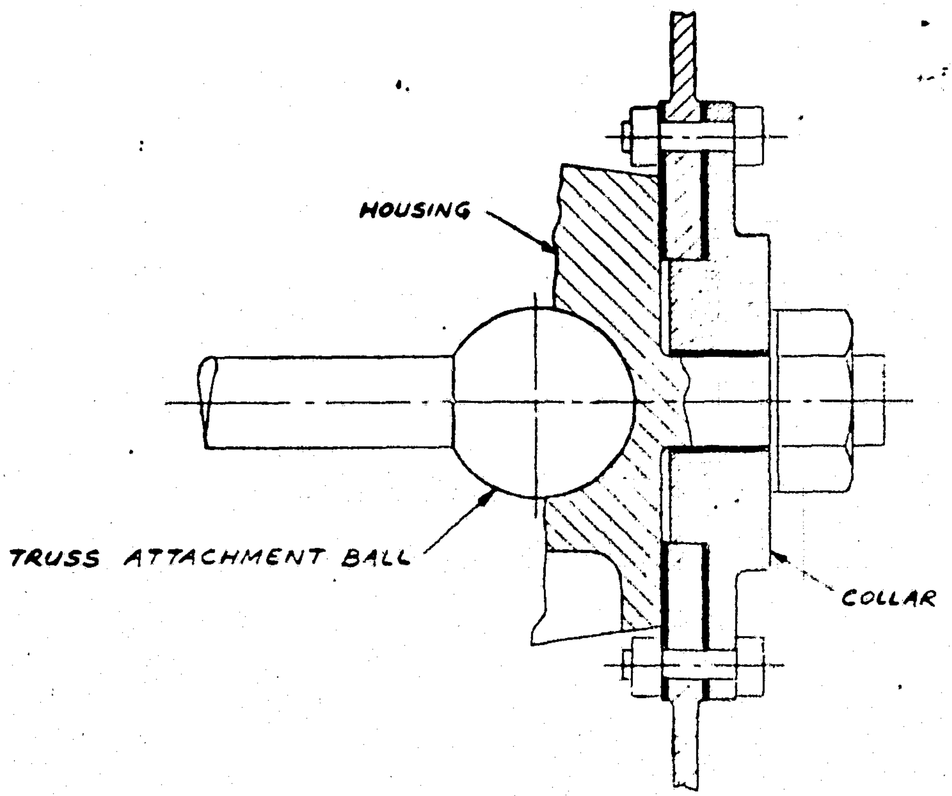


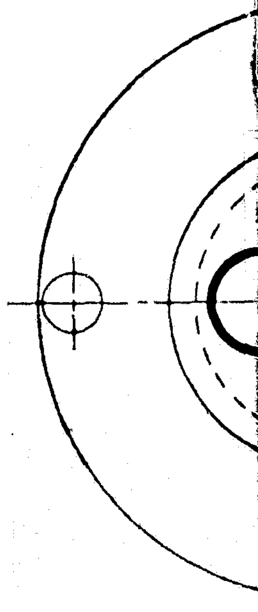
TYPE A





FLOATING CO



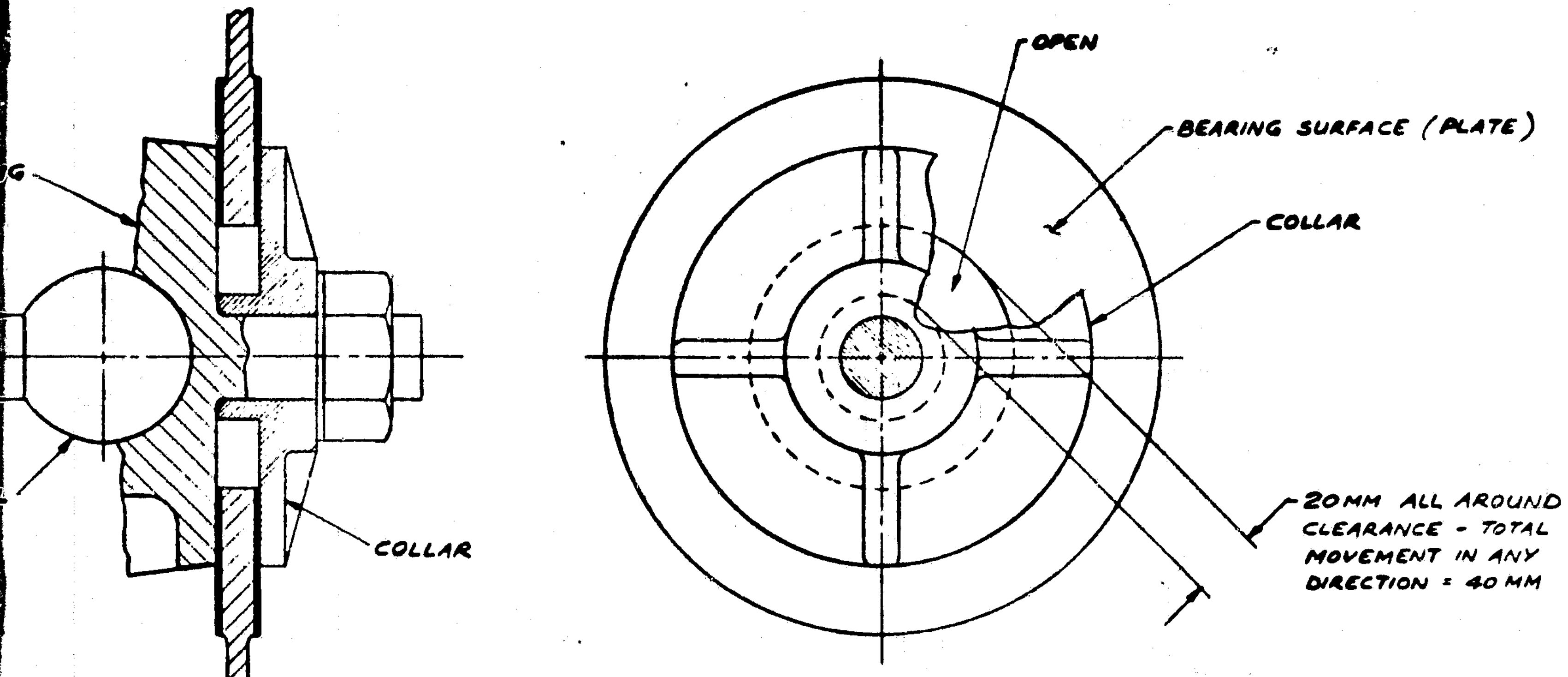


LINEAR ALLOWA

PORT STRUCTURE ATTACHMENT HOUSING DETAILS

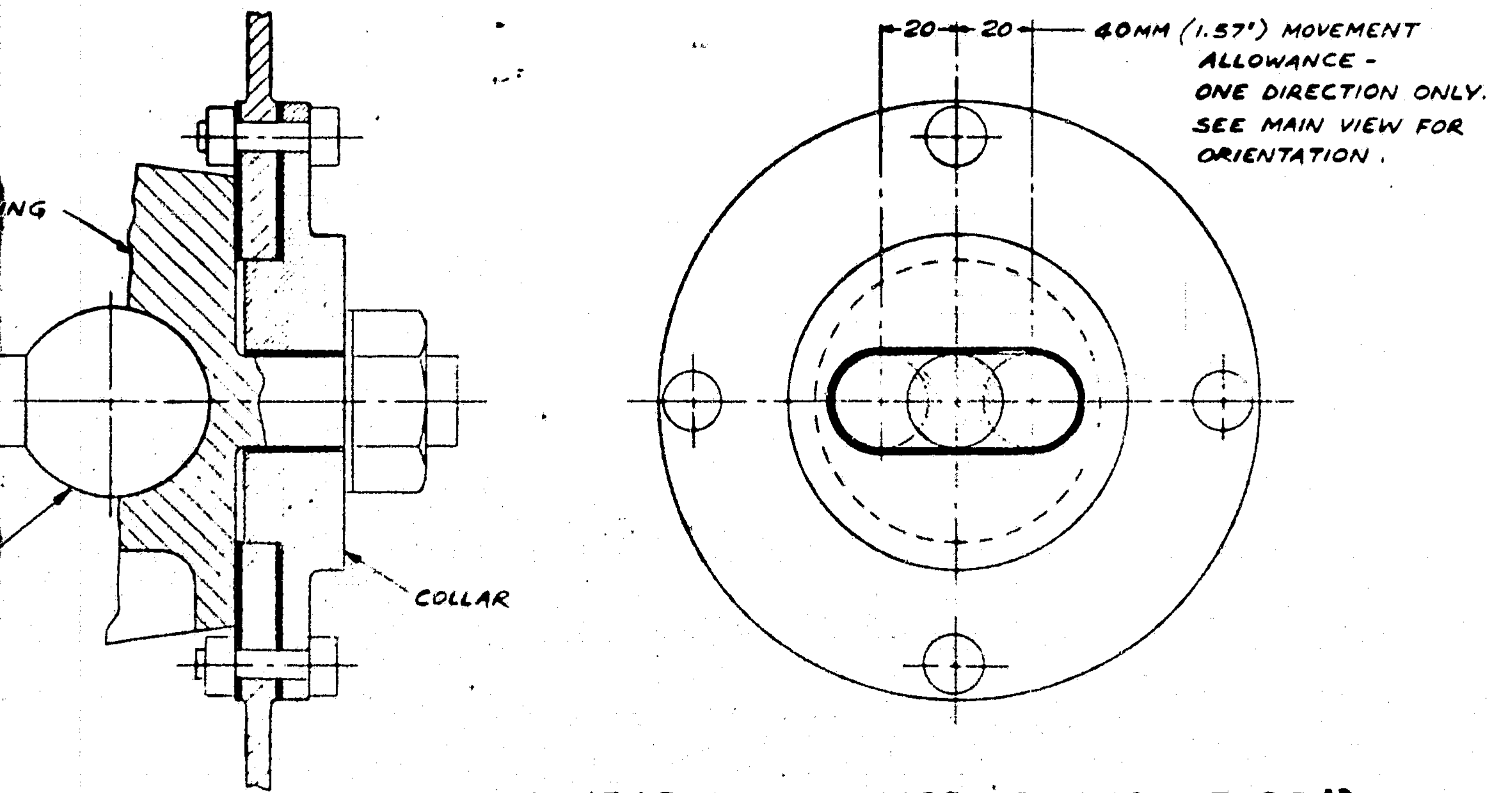
SCALE : FULL

3 FOLDOUT FRAME



FLOATING COLLAR - TYPE C

LIN
AT
HO
N

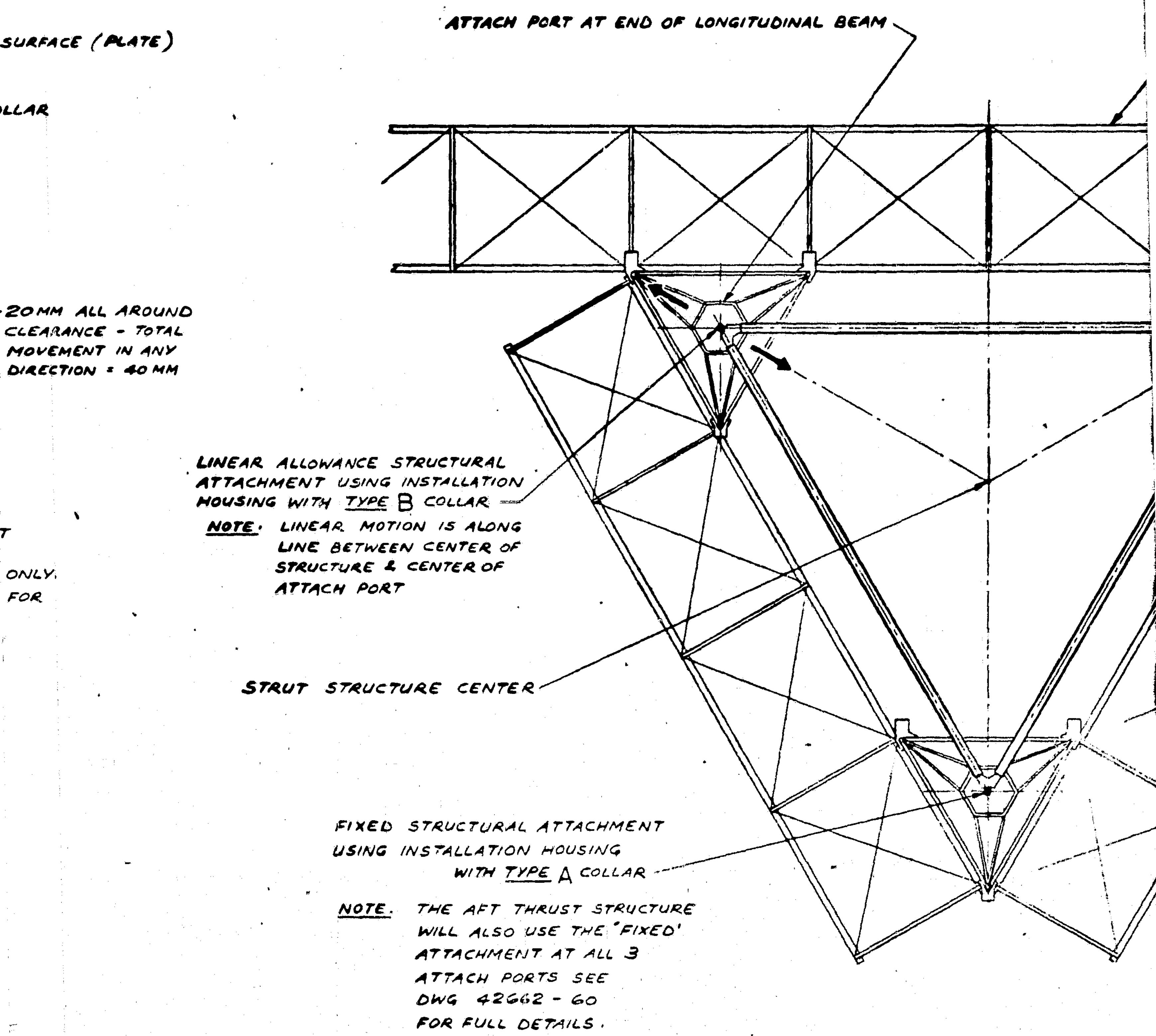


LINEAR ALLOWANCE COLLAR - TYPE B

SING DETAILS

4

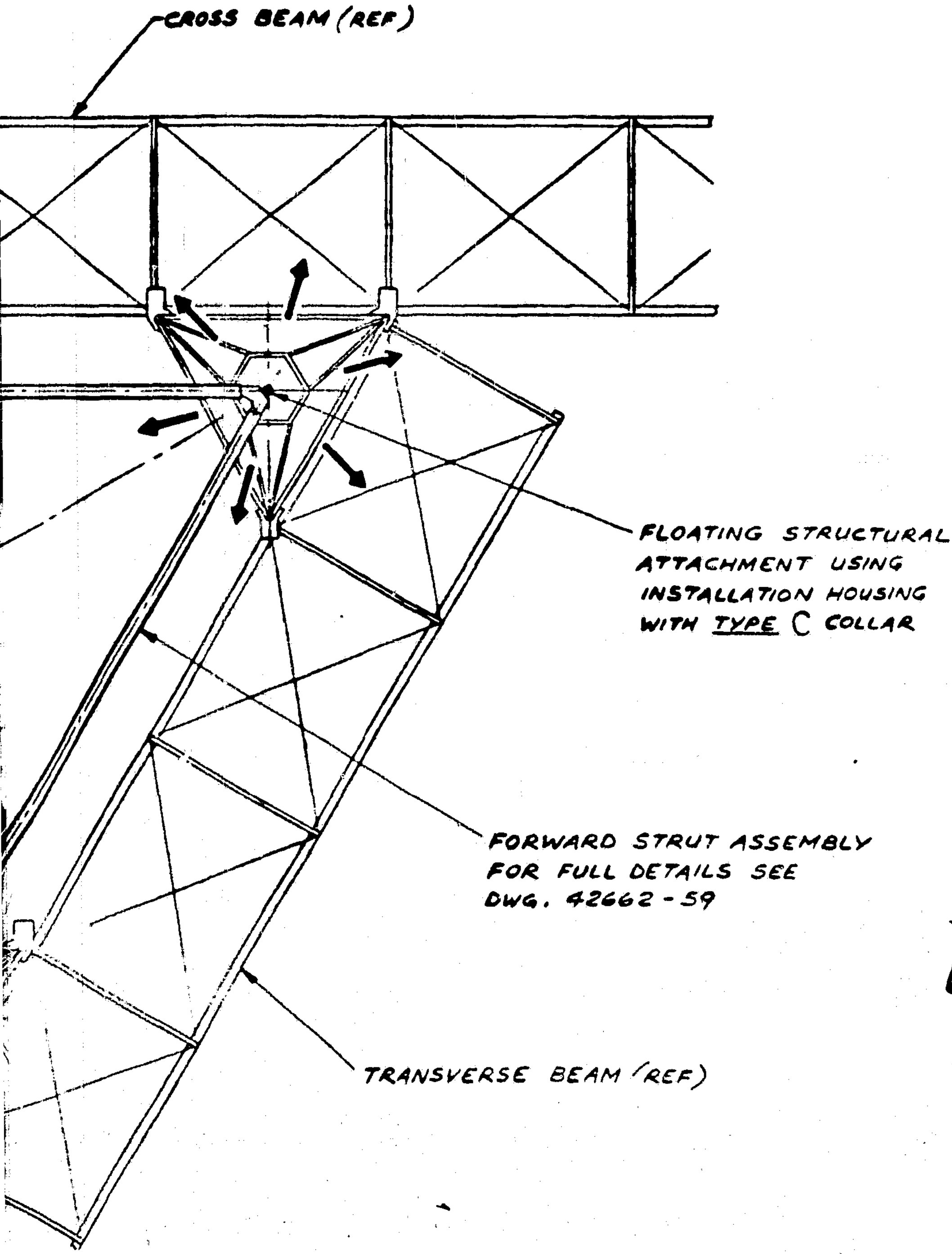
FOLDOUT FRAME



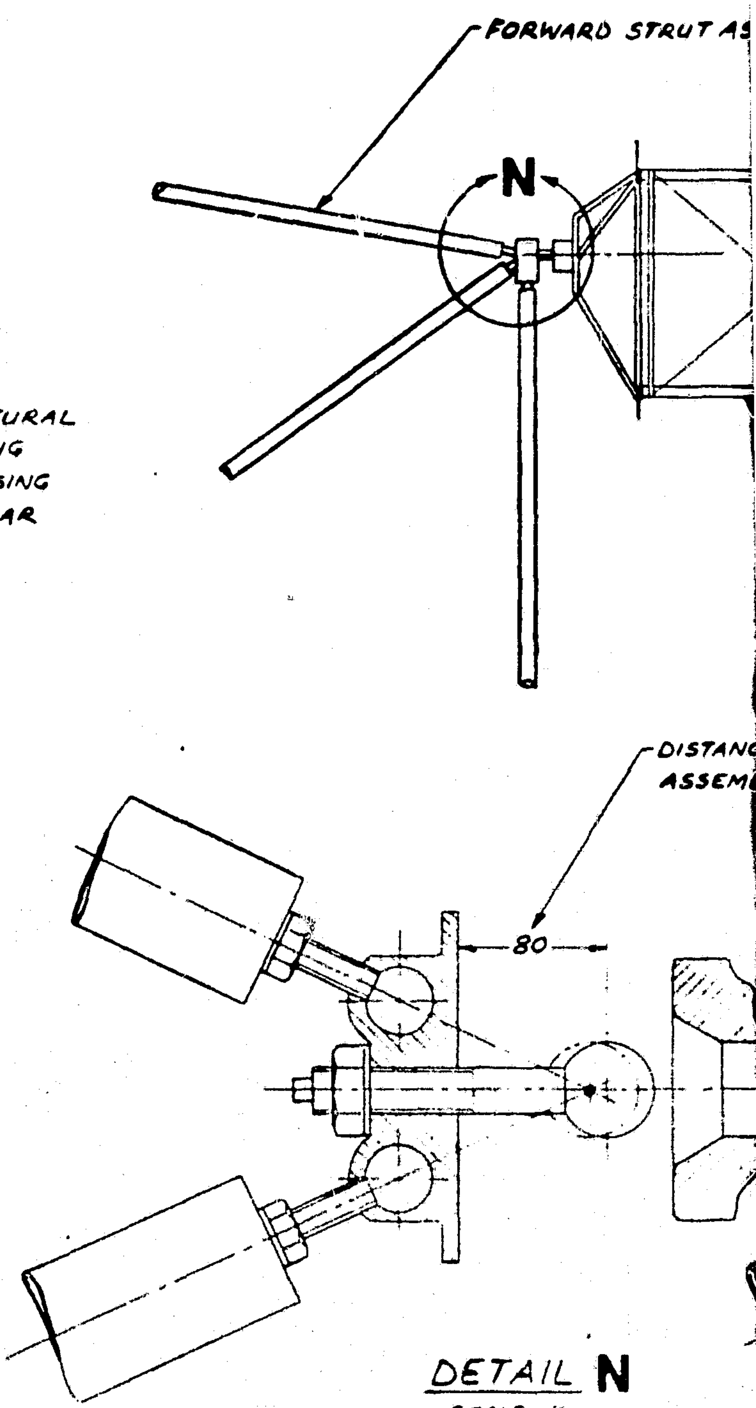
PLATFORM - FORWARD END VIE

SCALE: 1/20

5 FOLDOUT FRAME



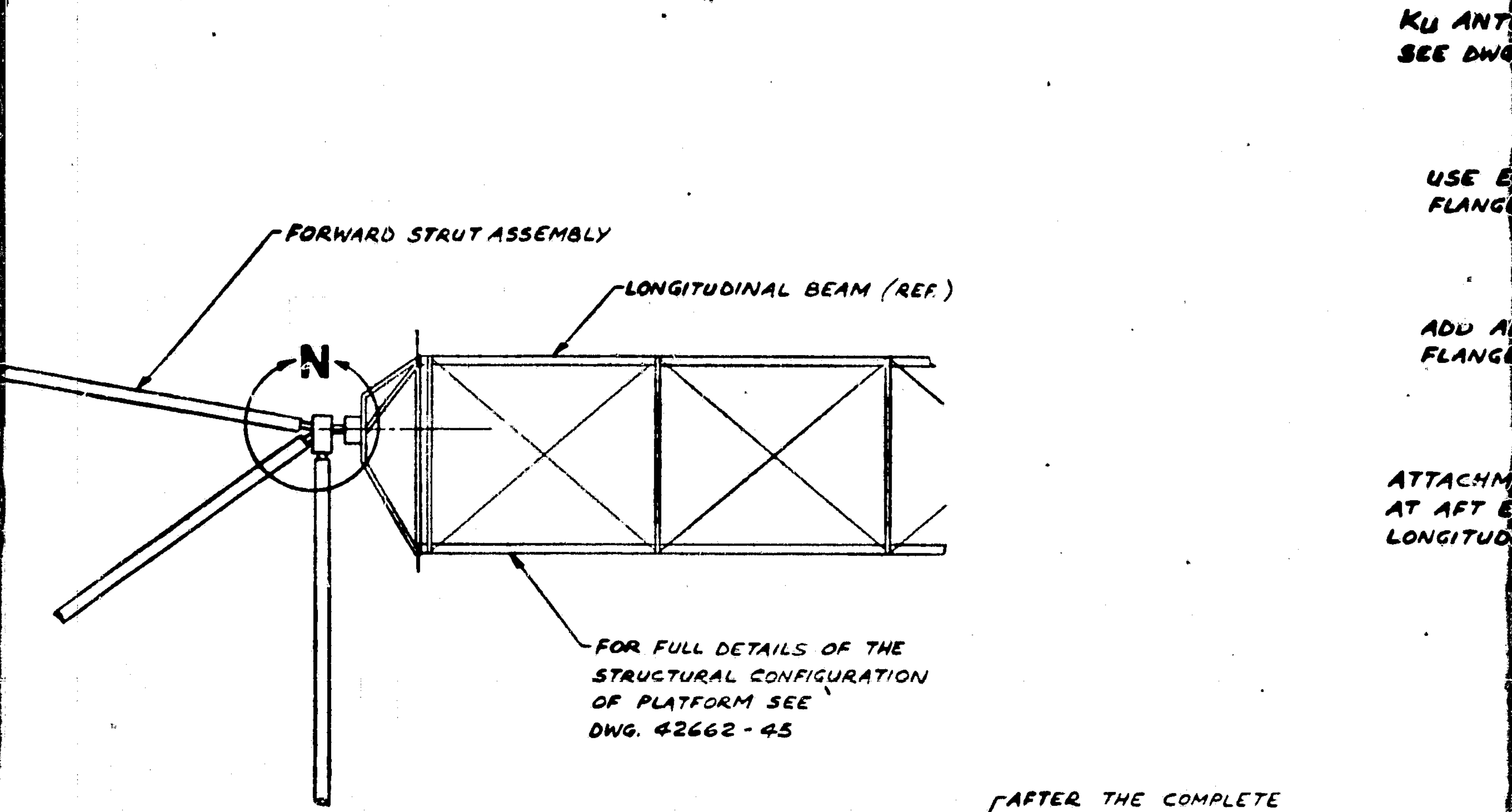
ND VIEW

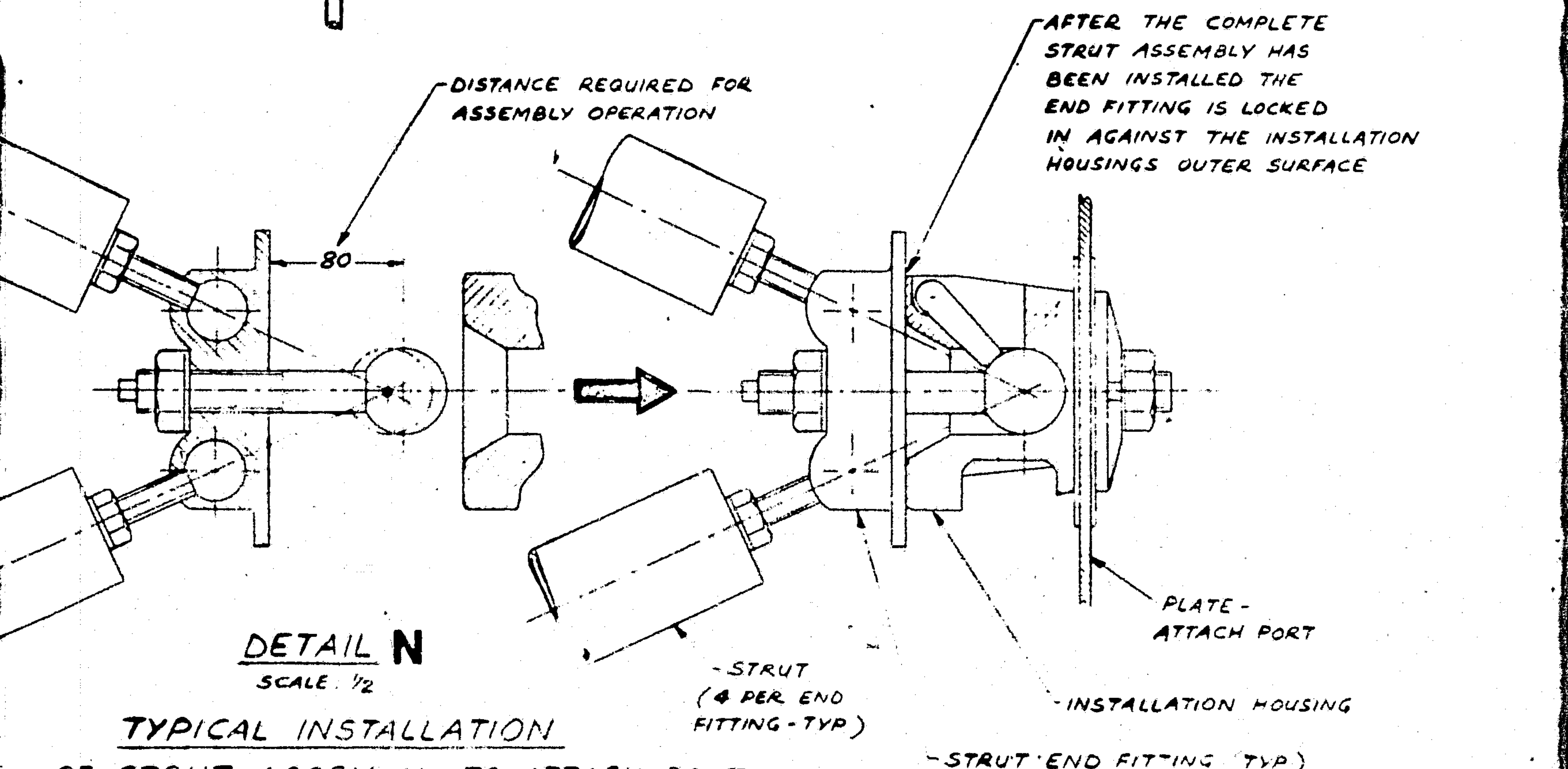


DETAIL N
SCALE 1/2

TYPICAL INSTALLATIO
OF STRUT ASSEMBLY TO A

6 FOLDOUT FRAME

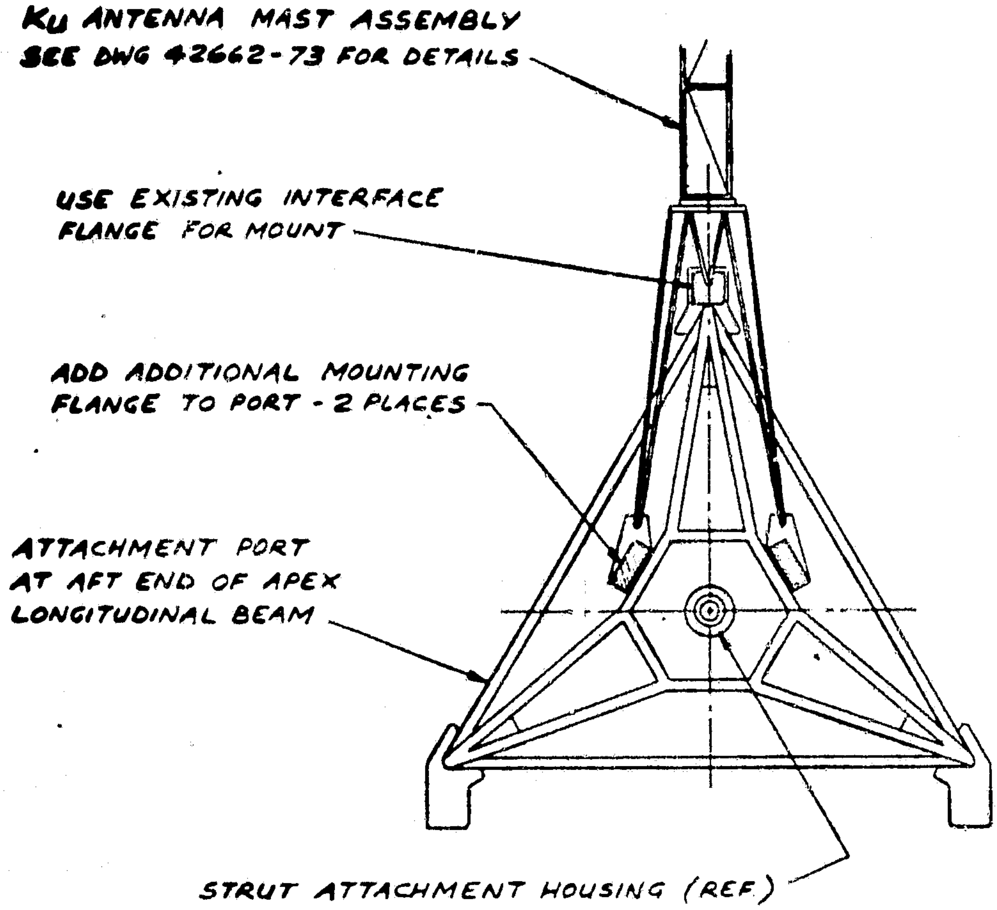




DETAIL N
SCALE 1/2

TYPICAL INSTALLATION
OF STRUT ASSEMBLY TO ATTACH PORT

FOLDOUT FRAME



ADDITION TO ATTACH PORT

ONE ONLY

SCALE: 1/10

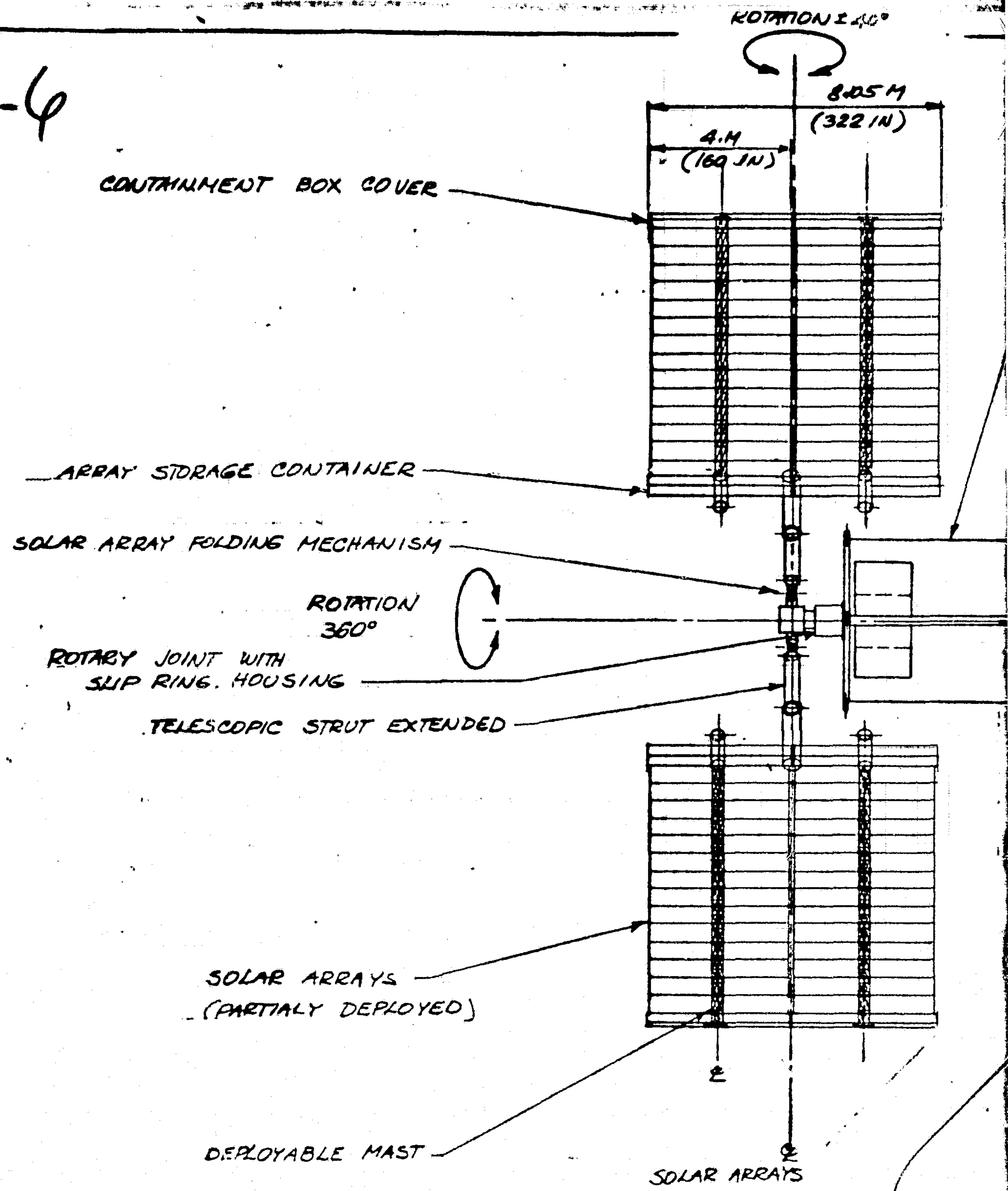
A-57,
A-58

Rockwell International		
MALE MODULE ATTACH PORT		42662-72 SHEET 2 OF 2

FOLDOUT FRAME

8

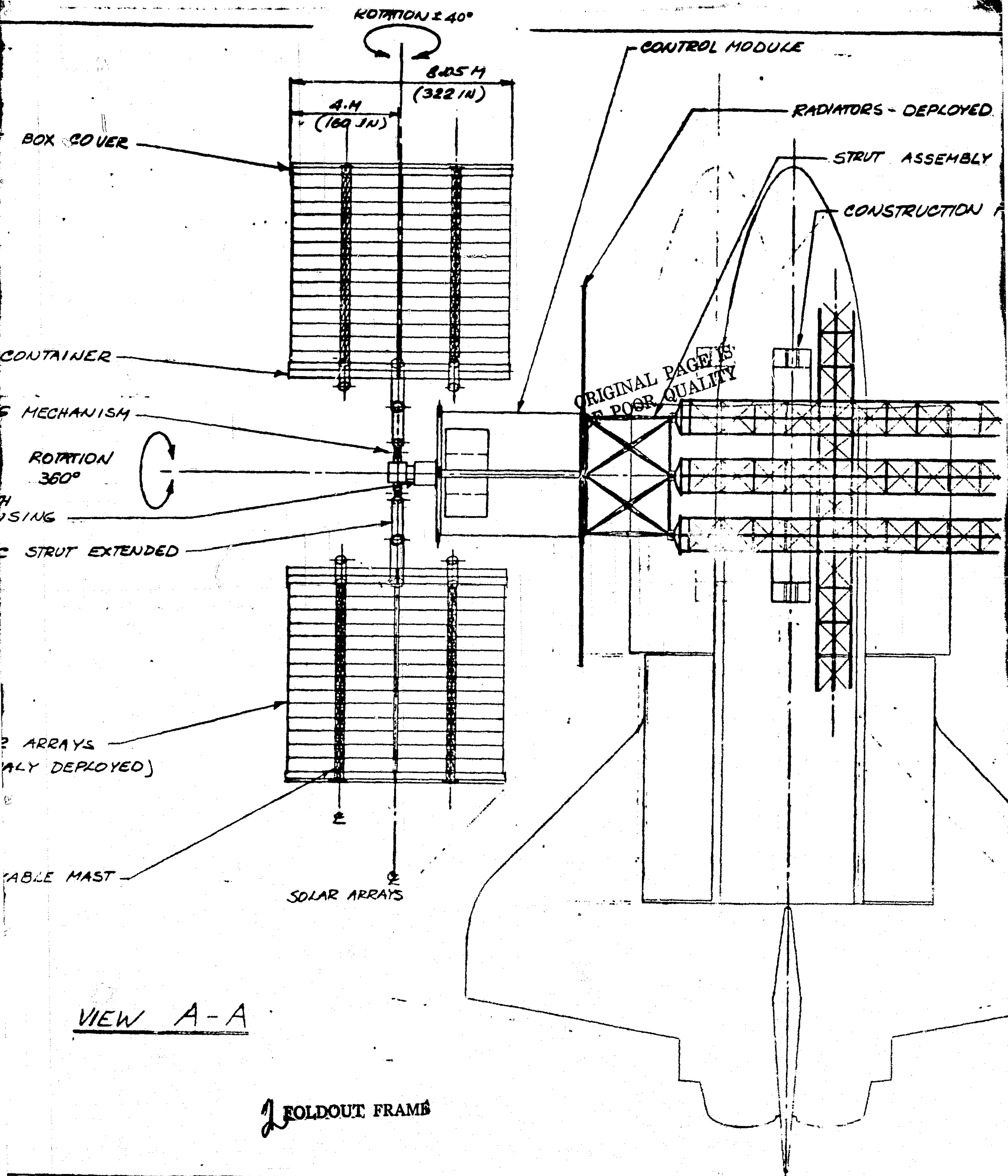
C-6



FOLDOUT FRAME

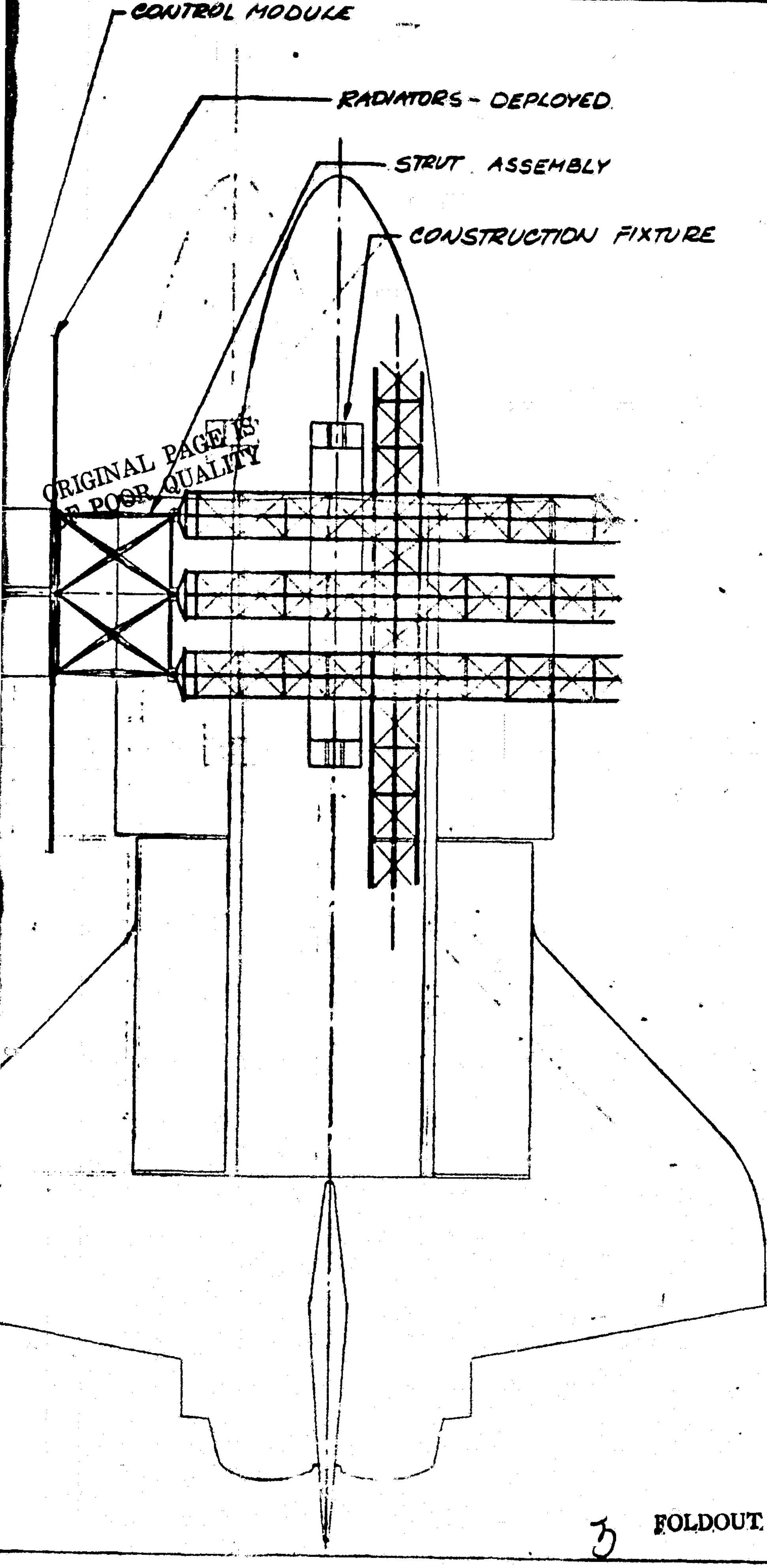
VIEW A-A

ORIGINAL PAGE IS
OF POOR QUALITY



VIEW A-A

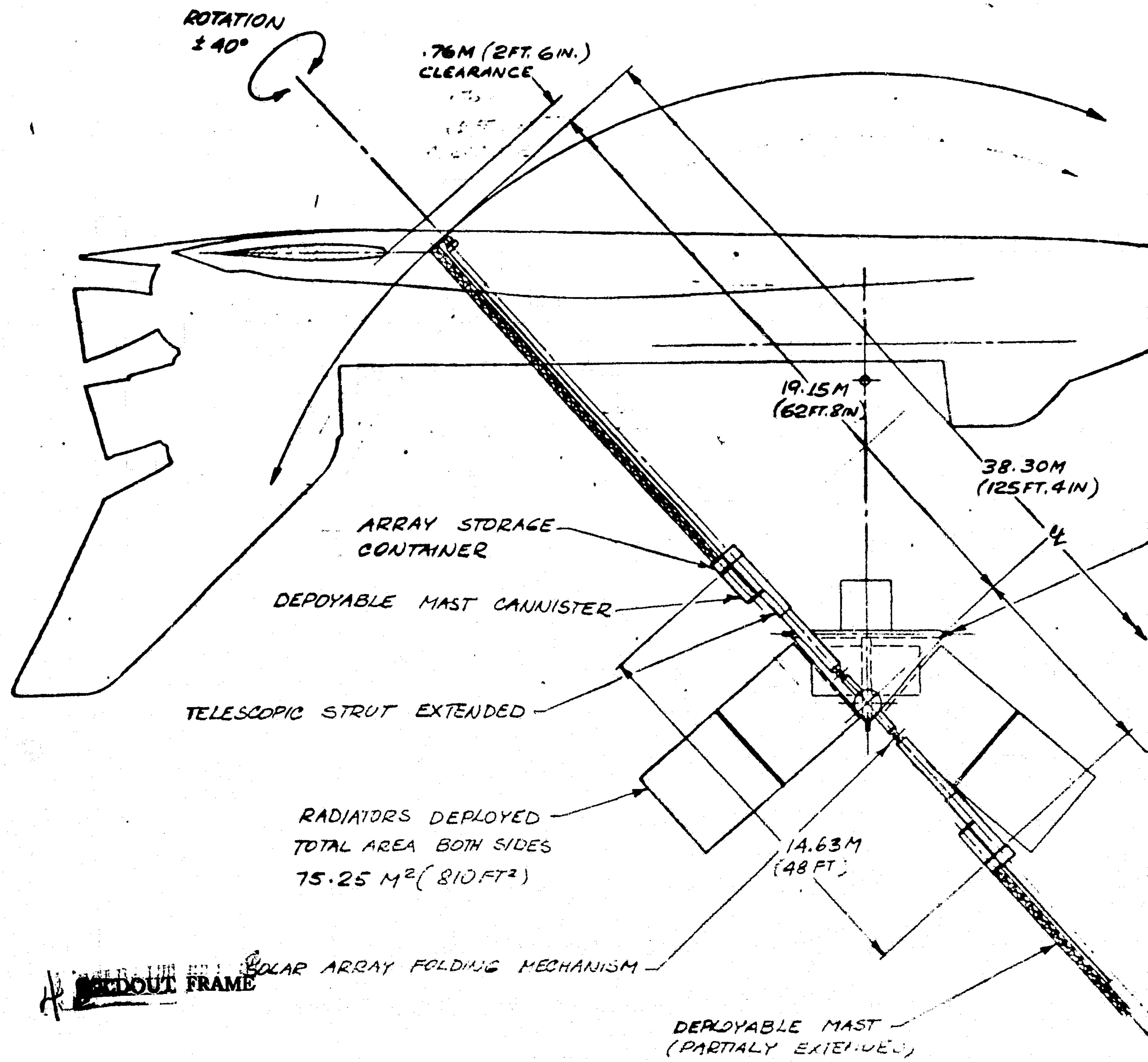
2 FOLDOUT FRAME



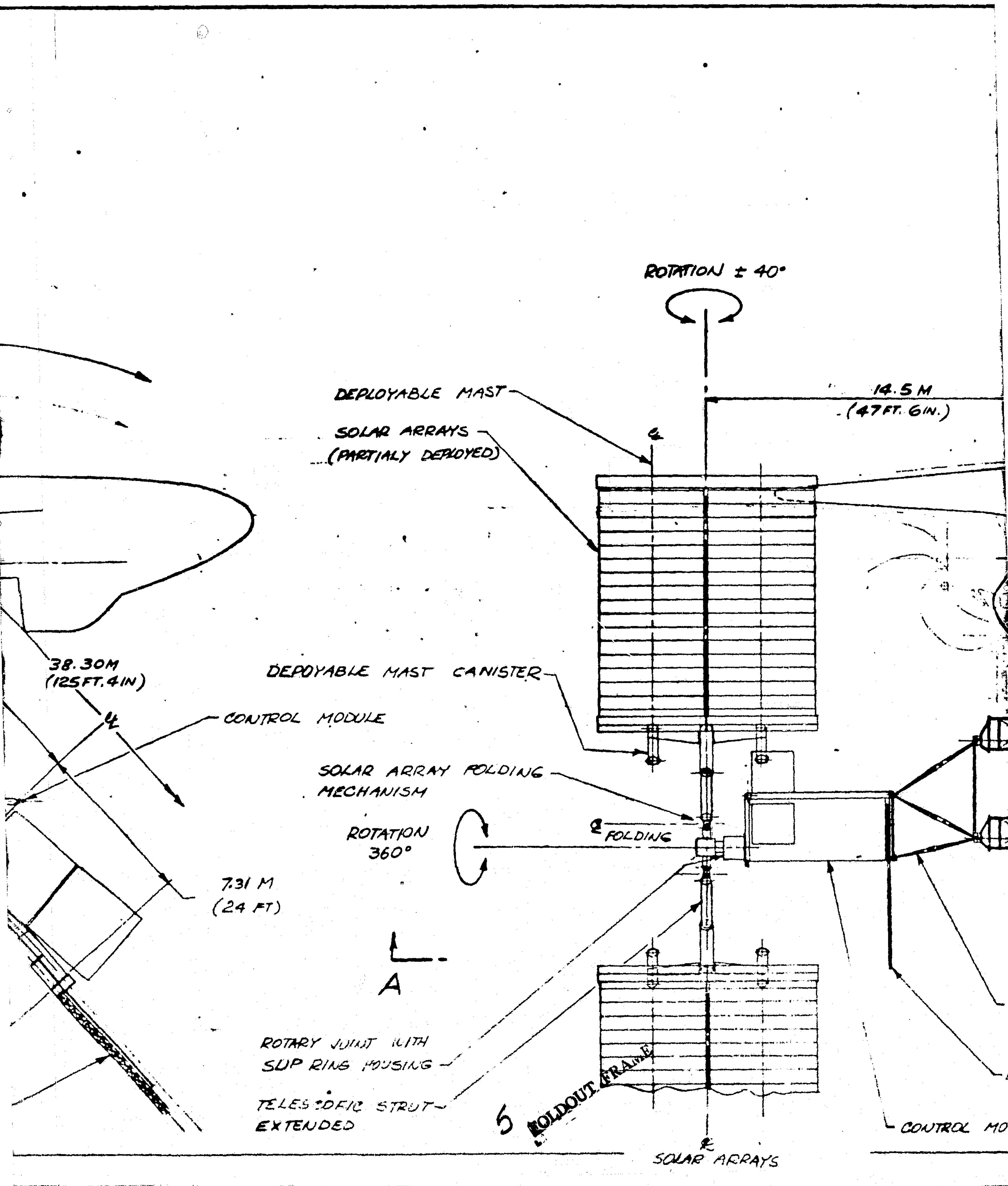
3 FOLDOUT FRAME

2

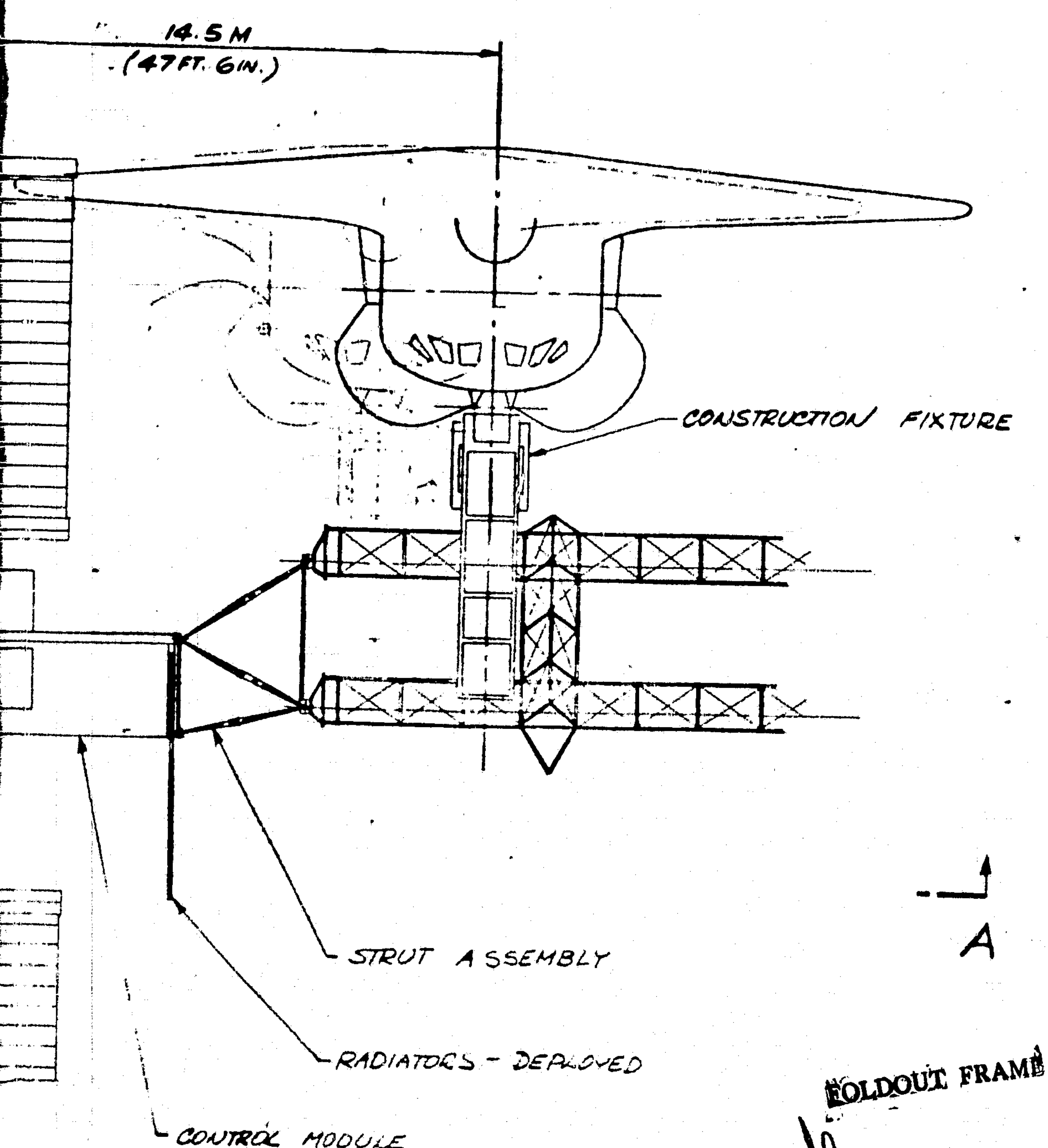
ORIGINAL PAGE IS
OF POOR QUALITY



FOLDOUT FRAME



5 FOLDOUT FRAME



OPERATIN
DOCKED OR

FOLDOUT FRAME

6

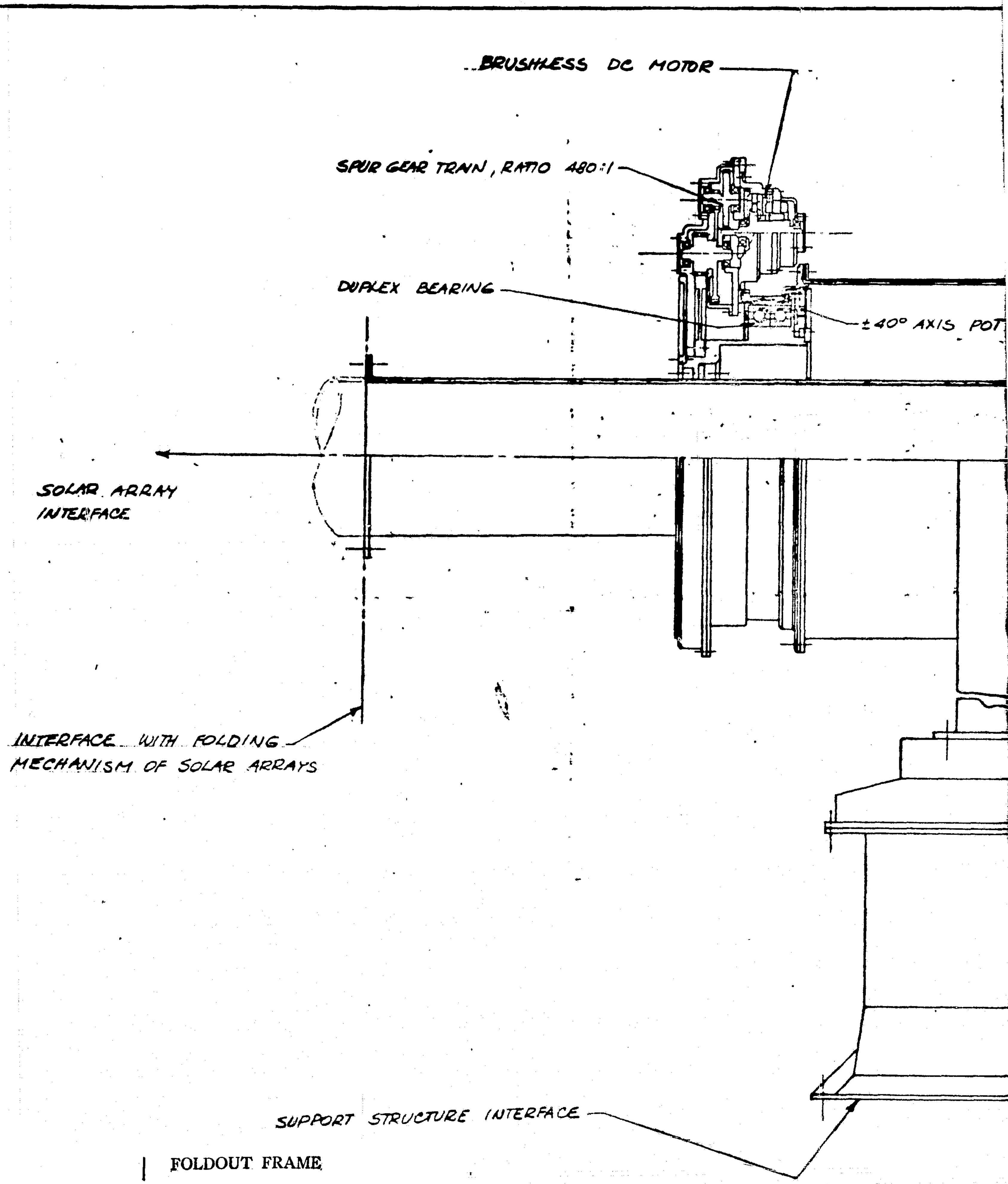
OPERATING MODE WITH
DOCKED ORBITER

A-59,
A-60

7 FOLDOUT FRAME

SHT 1 OF 2

SCALE 1/80 (NOTED)	BY / DATE / MODEL	Rockwell International	
SOLAR ARRAY ASSEMBLY			42662-74



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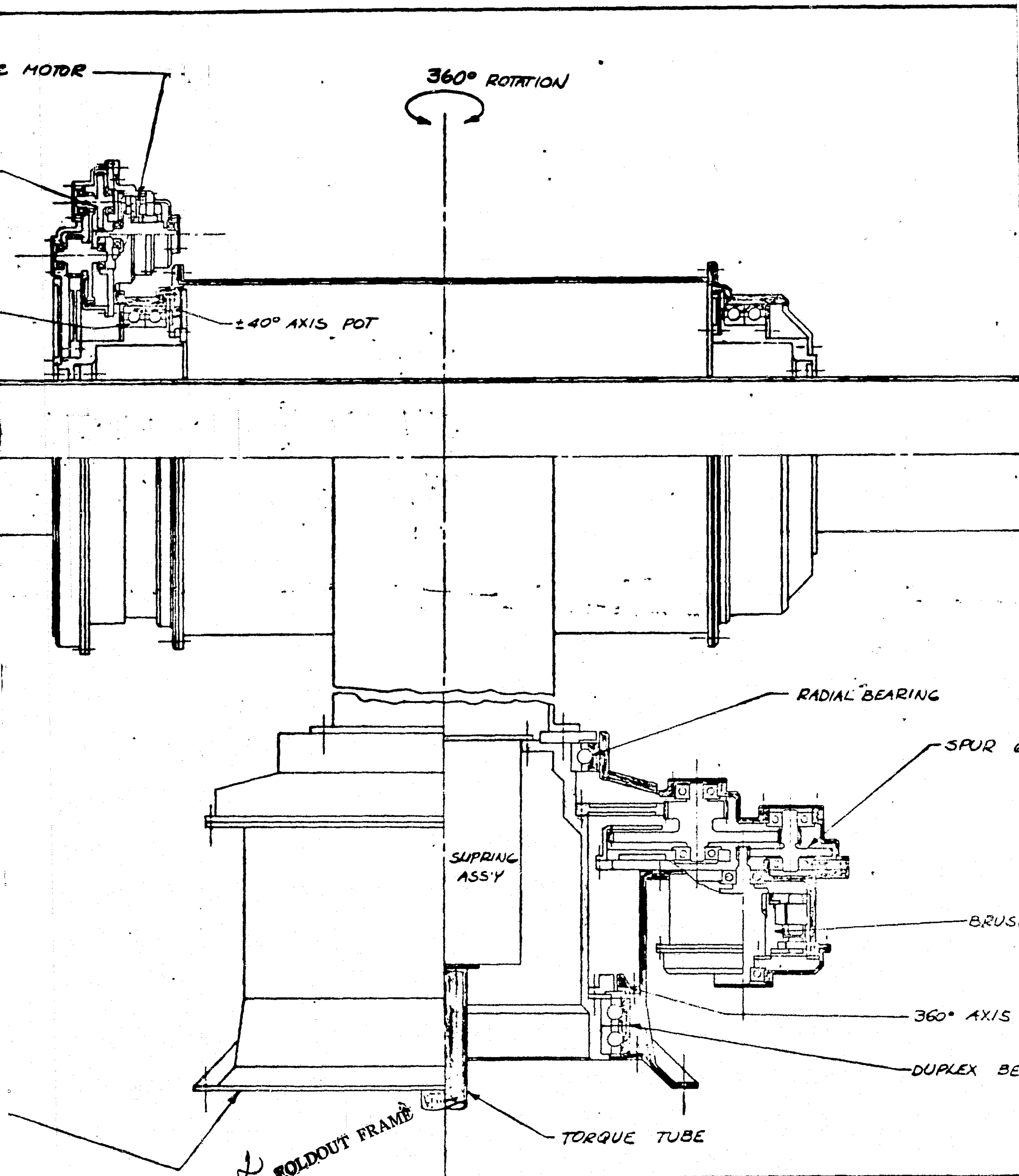

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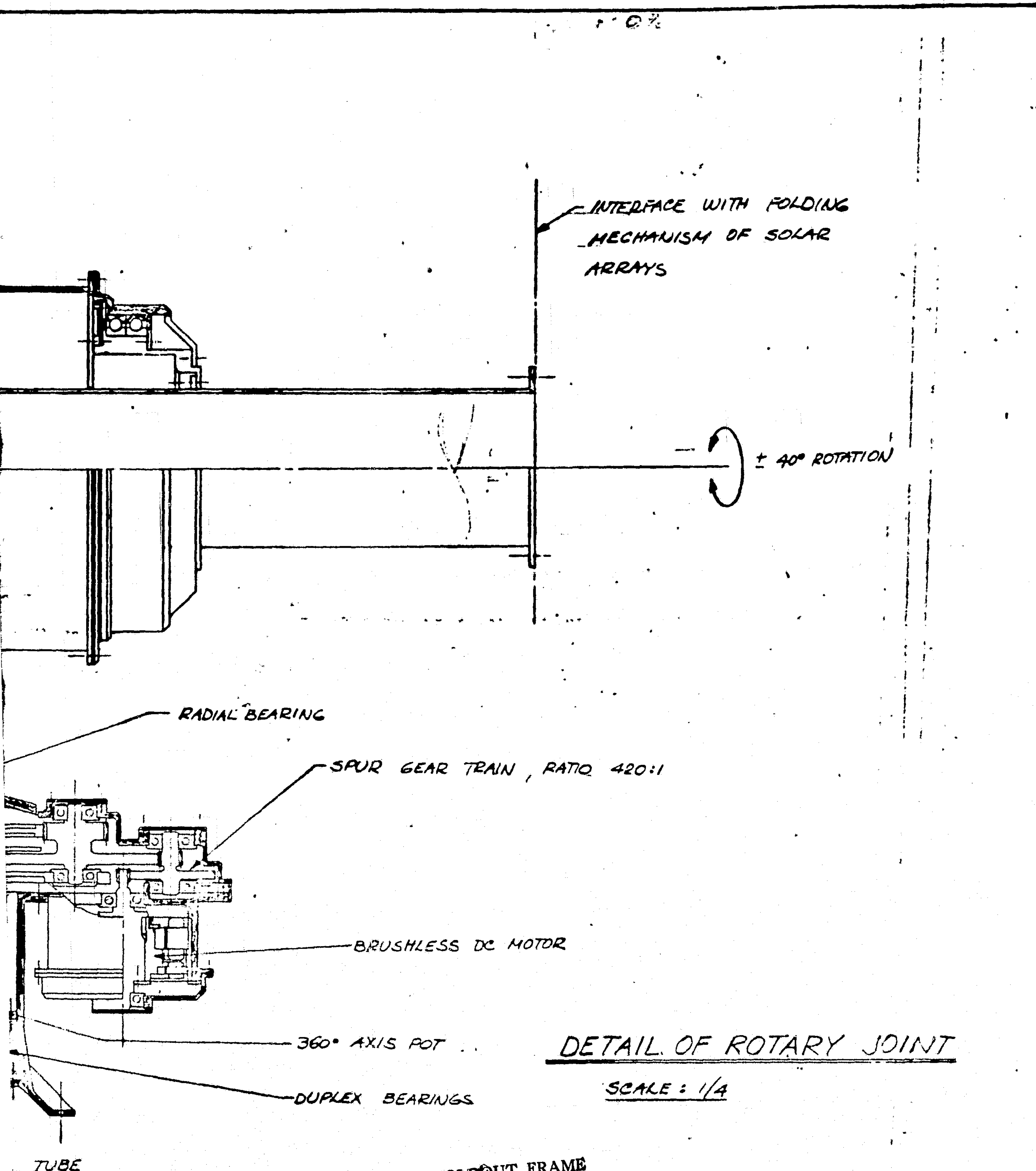
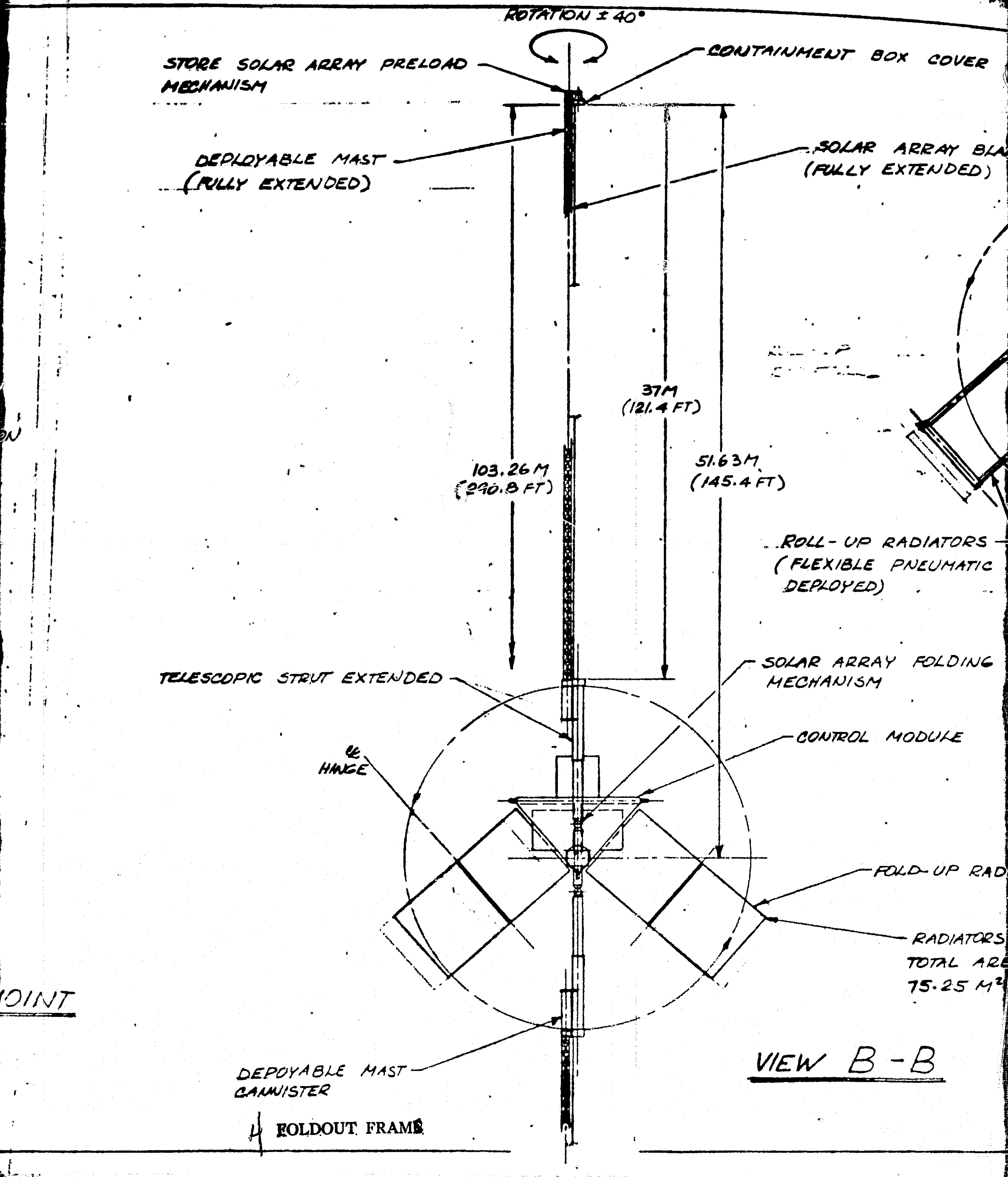
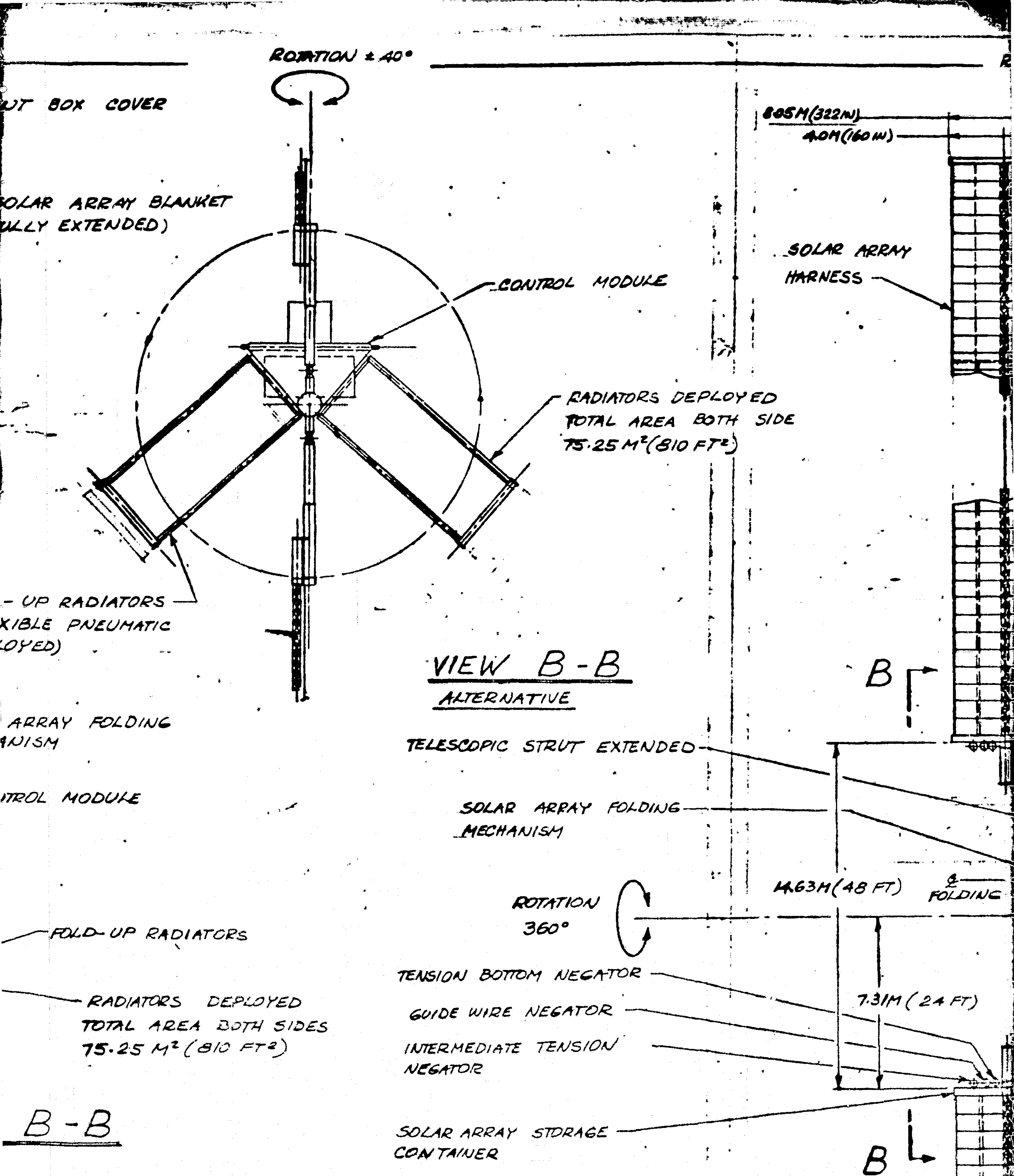


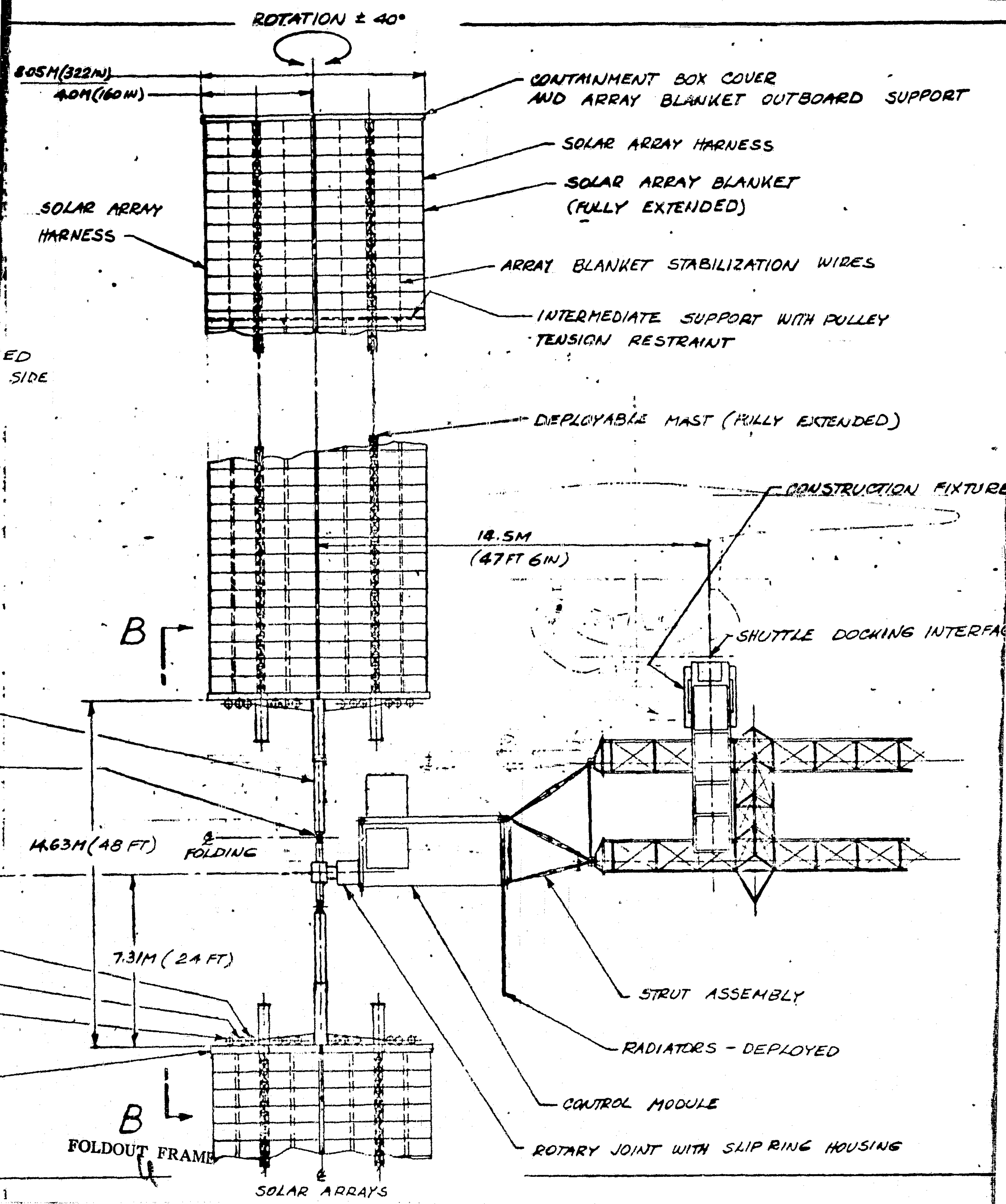
FOLDOUT FRAME 3



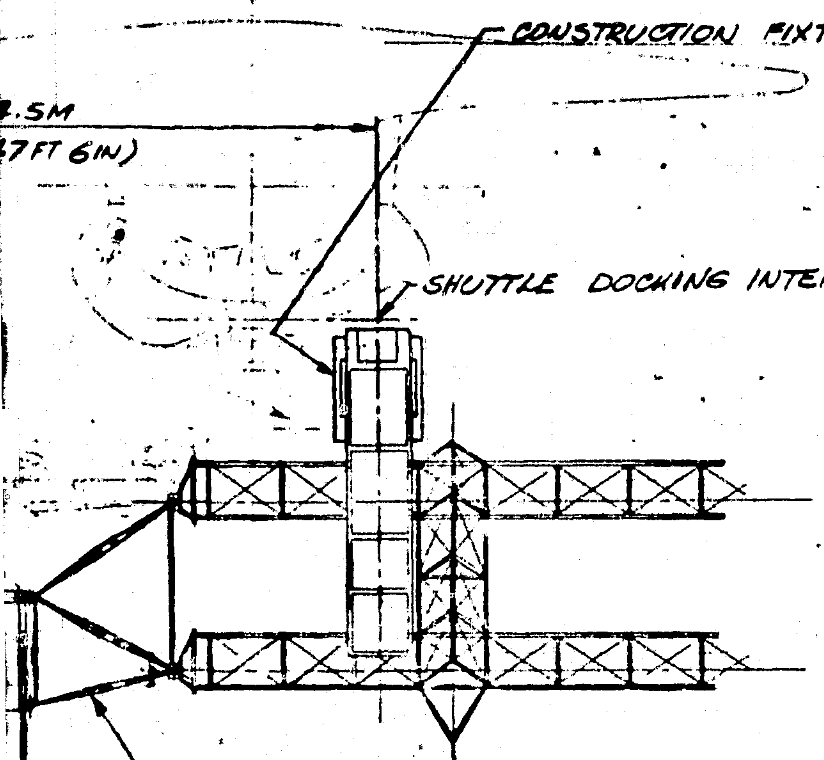
4 FOLDOUT FRAME



5 FOLDOUT FRAME



FOLDOUT FRAME



SOLAR ARRAY BLANKET AREA
(1 WING)

TOTAL SOLAR ARRAY BLANKET
(4 WINGS)

OPERATING MODE WITHOU
DOCKED ORBITER

FOLDOUT FRAME

SCALE 1/100 NOTED	Rockwell International

SOLAR ARRAY
ASSEMBLY

RT

IXTURE

TERFACE

SOLAR ARRAY BLANKET AREA = 148 M^2
(1 WING)

TOTAL SOLAR ARRAY BLANKET AREA = 592 M^2
(4 WINGS)

OPERATING MODE WITHOUT
DOCKED ORBITER

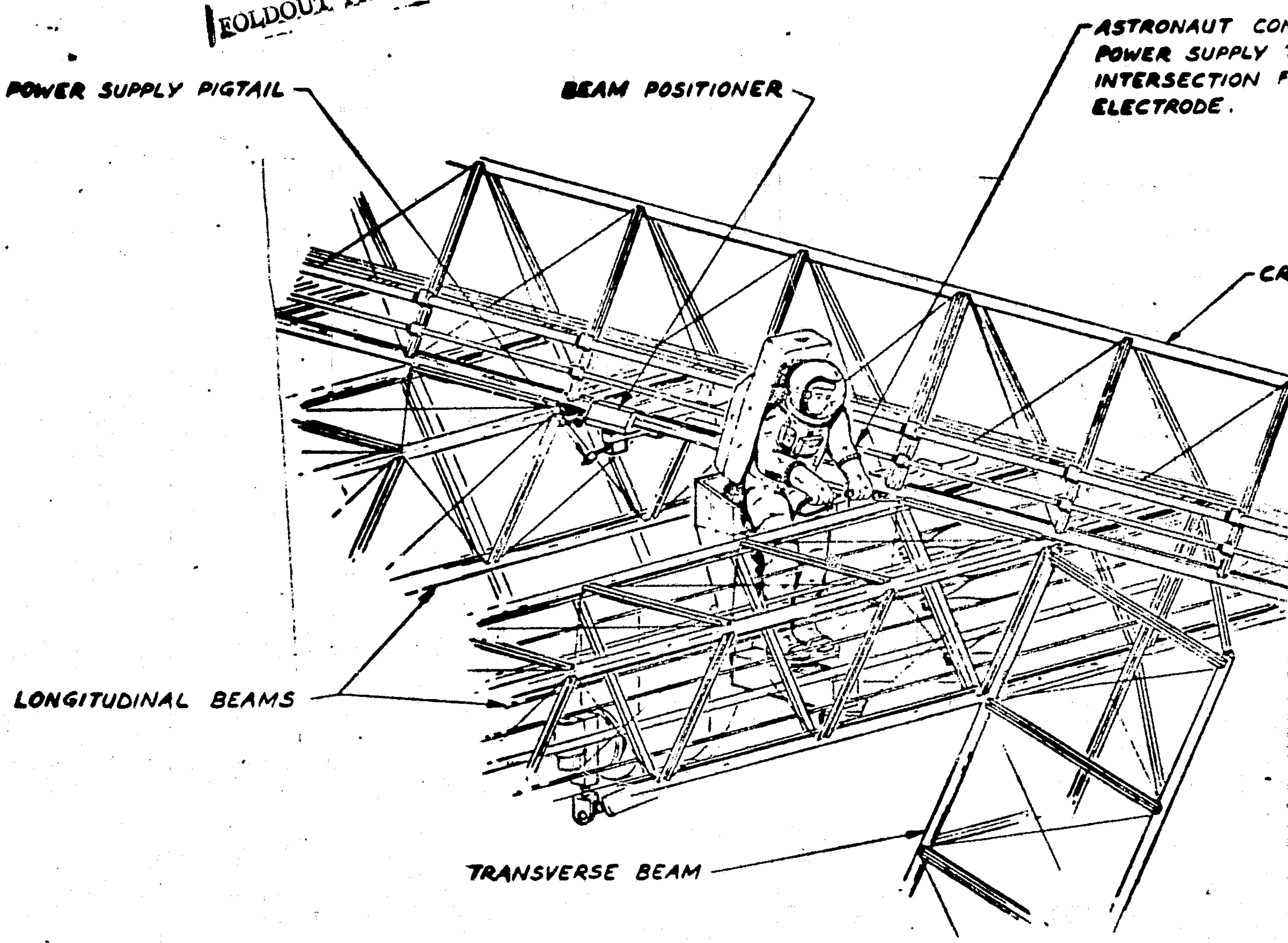
SHT 2 OF 2

A-61,
A-62

1/80 NOTED		Rockwell International	
SOLAR ARRAY ASSEMBLY			42662-74

8 FOLDOUT FRAME

FOLDOUT FRAME



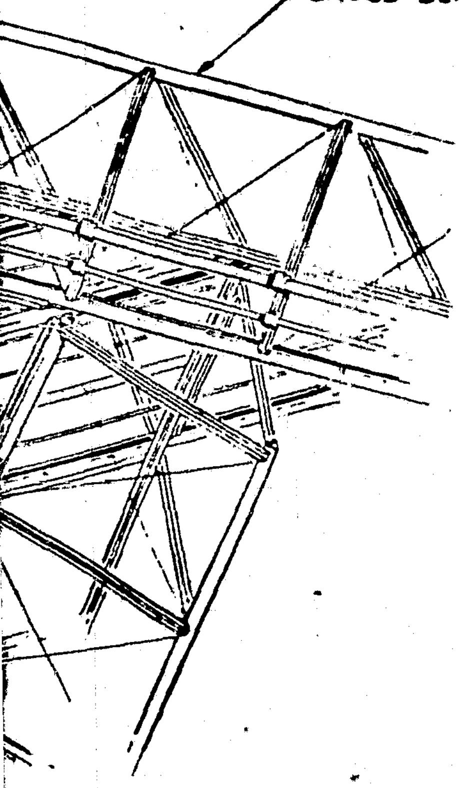
(5) POWER SUPPLY HOOK-UP TO INTERSECTION FITTING.

NOTE -

- ASTRONAUT TAKES POWER SUPPLY PIGTAIL FROM LOCATION ON BEAM POSITIONER AND CONNECTS SAME TO ELECTRODE ON THE INTERSECTION FITTING BETWEEN CROSS BEAM AND THE LONGITUDINAL BEAM.
- THE CHERRY PICKER IS TRANSLATED TO THE ADJACENT LONGITUDINAL BEAM WHERE THE PROCEDURE IS REPEATED.
- BOTH INTERSECTION FITTINGS REMAIN CONNECTED FOR THE REQUIRED "COOKING" PERIOD (THE ASTRONAUT IS FREE TO PERFORM OTHER DUTIES DURING THIS TIME, IF CONSIDERED PRACTICAL.)
- THE CROSS BEAM IS NOW WELDED TO THE LONGITUDINAL BEAM. AND THE POWER SUPPLY PIGTAILS ARE REMOVED.
- THE ABOVE PROCEDURE IS REPEATED FOR BOTH TRANSVERSE BEAMS. (TOTAL 3 SIDES - 6 CONNECTIONS)

FRAME

ASTRONAUT CONNECTING POWER SUPPLY TO INTERSECTION FITTING ELECTRODE.



TTING.

CATION ON
ON THE

IT
TED.

THE REQUIRED
RM OTHER

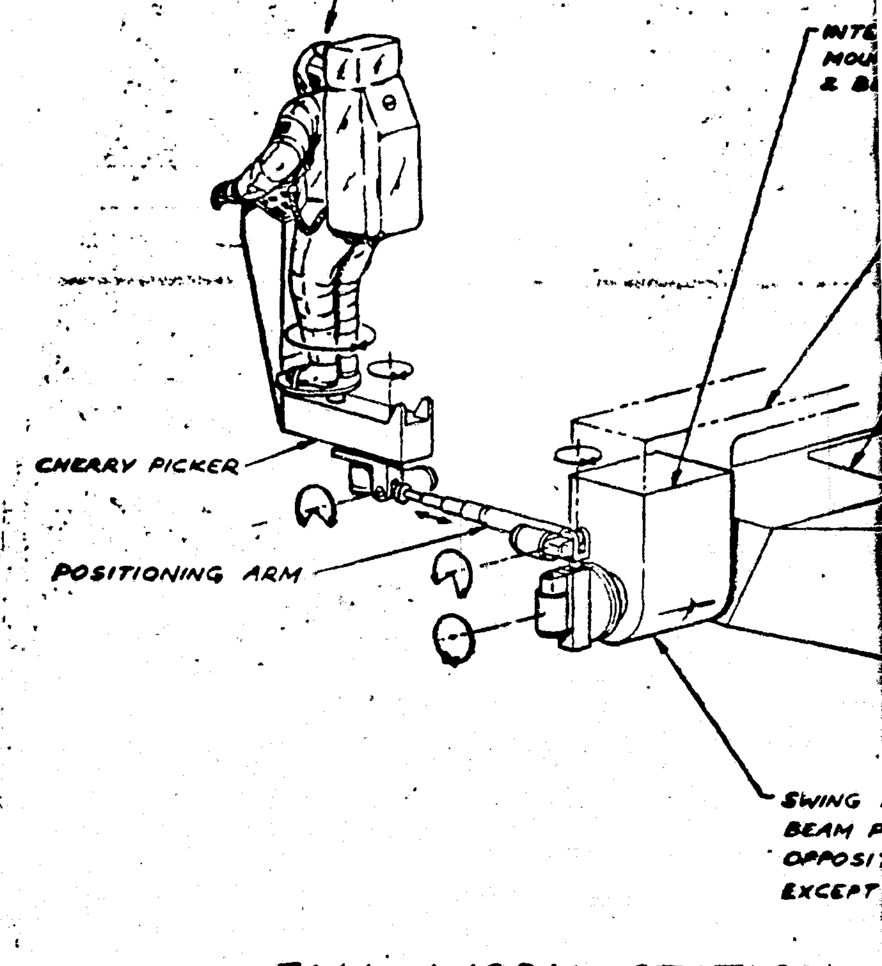
. BEAM.

VERSE BEAMS.

1 FOLDOUT FRAME

EVA FUNCTIONS

- EVA OBSERVATION GUIDANCE
- ALIGN BEAM POSITIONER FO
- SUPERVISE TRANSVERSE &
- APPLY ELECTRODES TO SELF
- VERIFICATION OF STRUCTURA
- TRANSLATE DIAGONAL CORDS
- CONNECT TENSION CORDS TO
- CHECK STRUCTURAL ALIGNM
- RELEASE ELECT. PIG TAILS FR
- MAKE ELECTRICAL CONNECTI



EVA WORK STATION

(4) ASTRONAUT ABOARD CHERRY PICKER RE
THE FOLLOWING MANUAL FUNCT

EAM HANDLING.
VIA. RMS DELIVERY.
EMBLIES.
ECTION FITTINGS.
CONTROL OF BEAM POSITIONER.
TUDINAL BEAMS.
ITTINGS EARS.
DIAGONAL CORDS.
& CROSS BEAMS.
RE LINES.

FOR
VINE

TIONER (REF.)

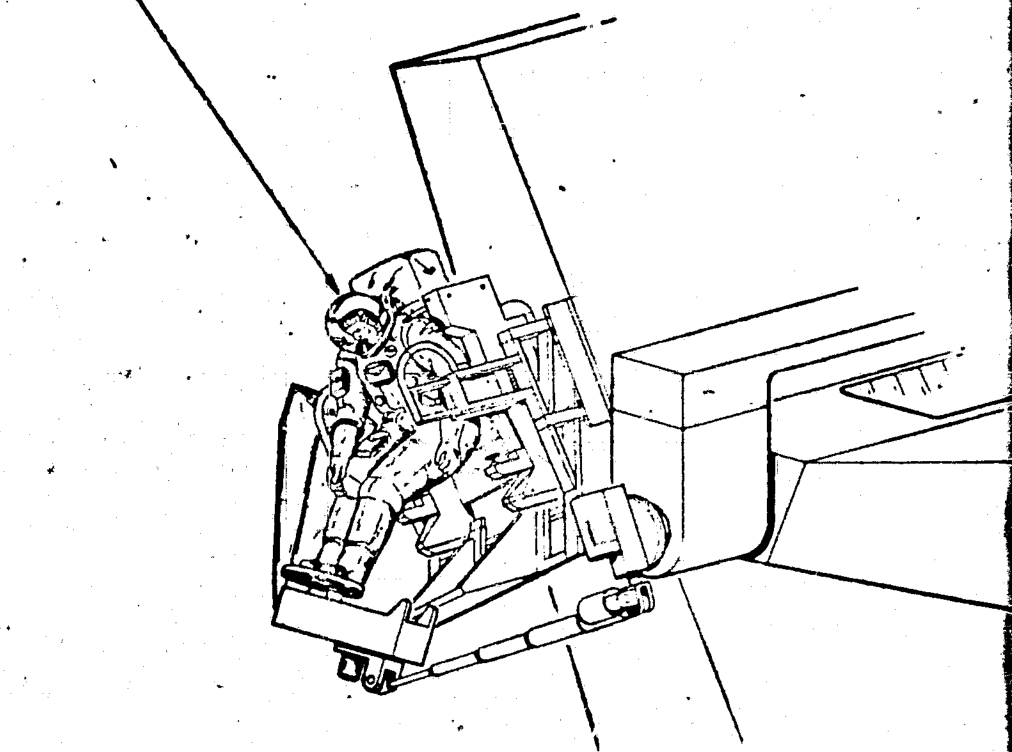
STATION Nº1
EXTENSION

WITH
ATED
G PLANE,
EMBLY OPERATIONS.

ERFORM

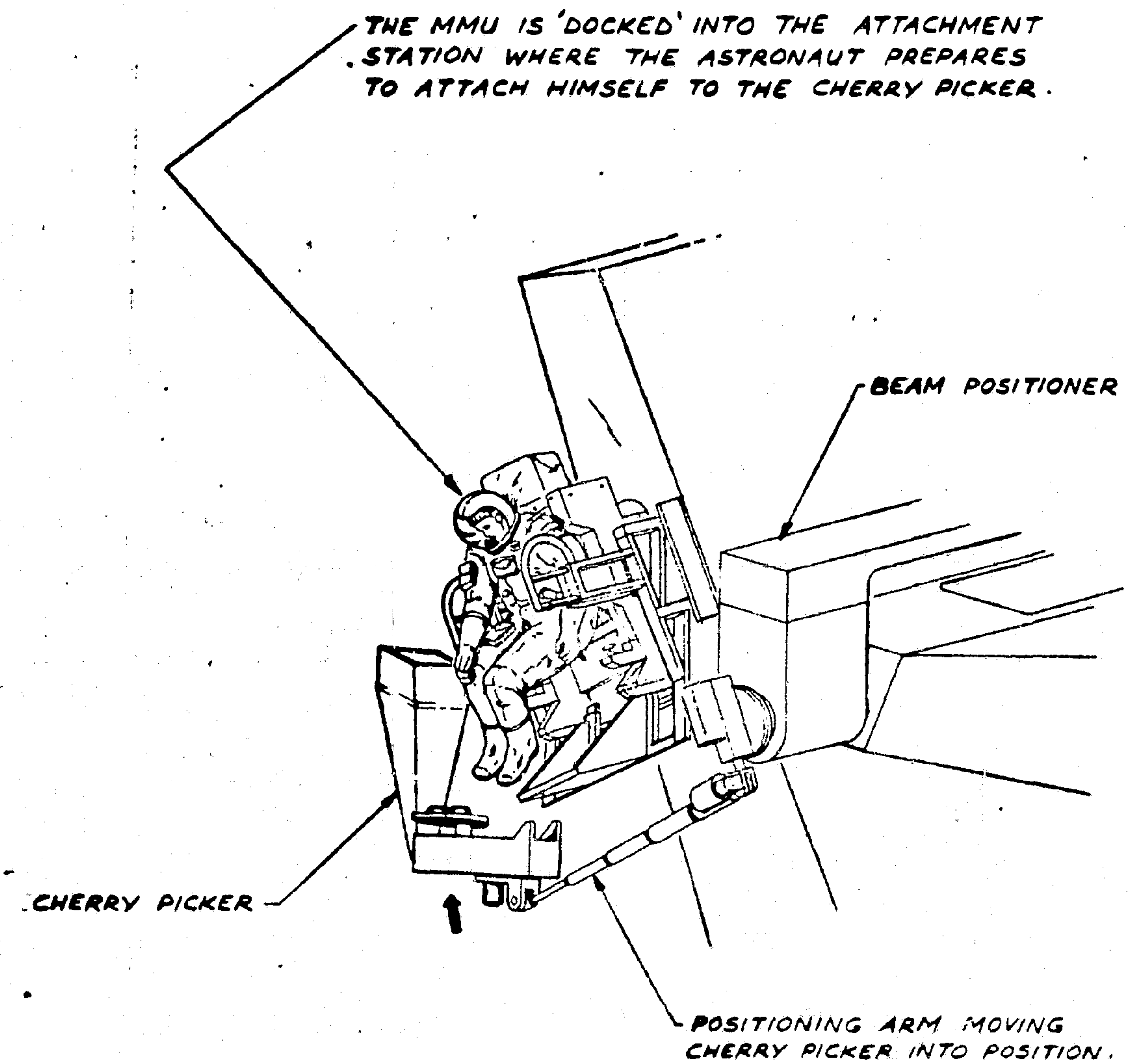
3 FOLDOUT FRAME

WITH THE CHERRY PICKER IN POSITION THE ASTRONAUT SECURES HIS FEET INTO THE FOOT RESTRAINT, SECURES SAFETY TETHER (NOT SHOWN) AND RELEASES HIMSELF FROM THE MMU.



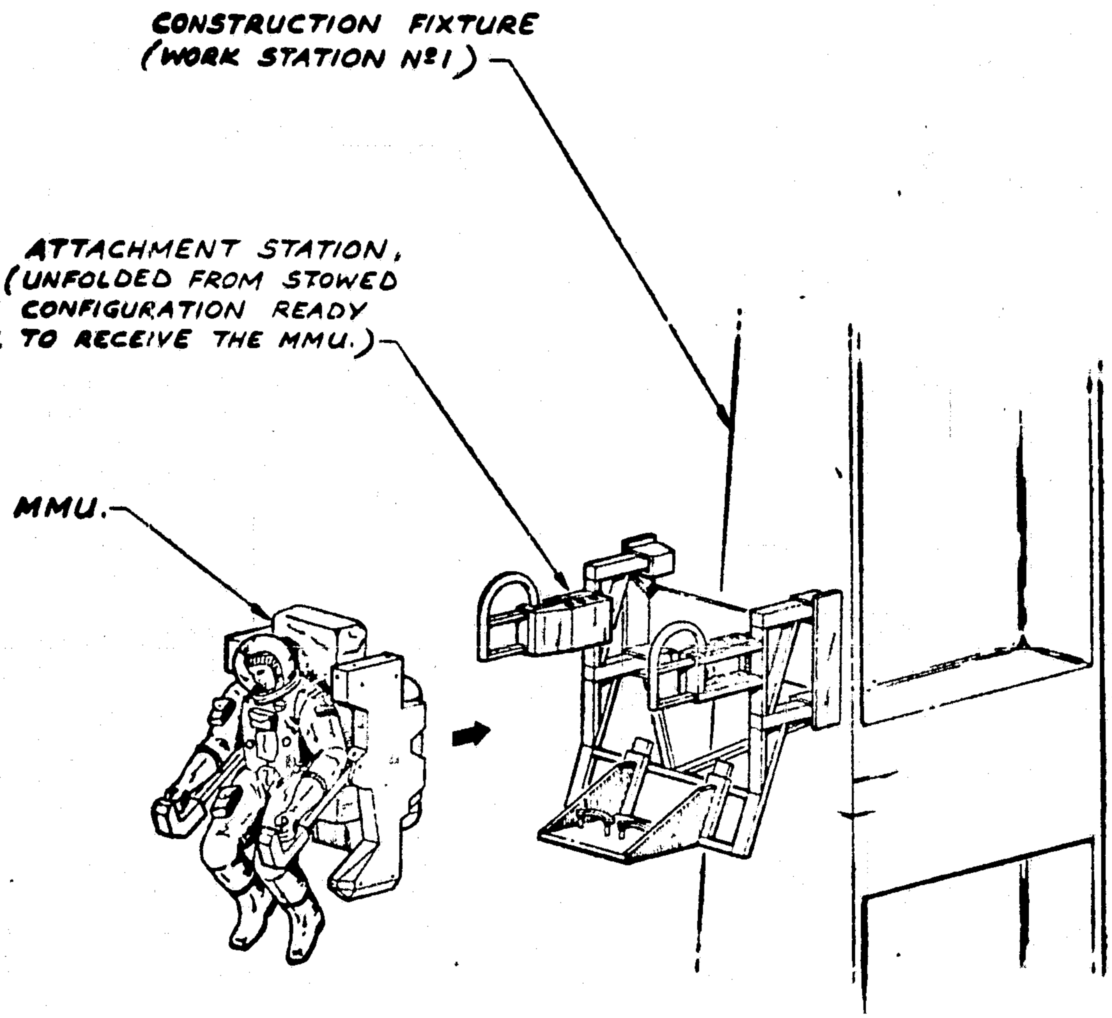
(3) ASTRONAUT SECURING FEET INTO CHERRY PIC

4 FOLDOUT FRAME



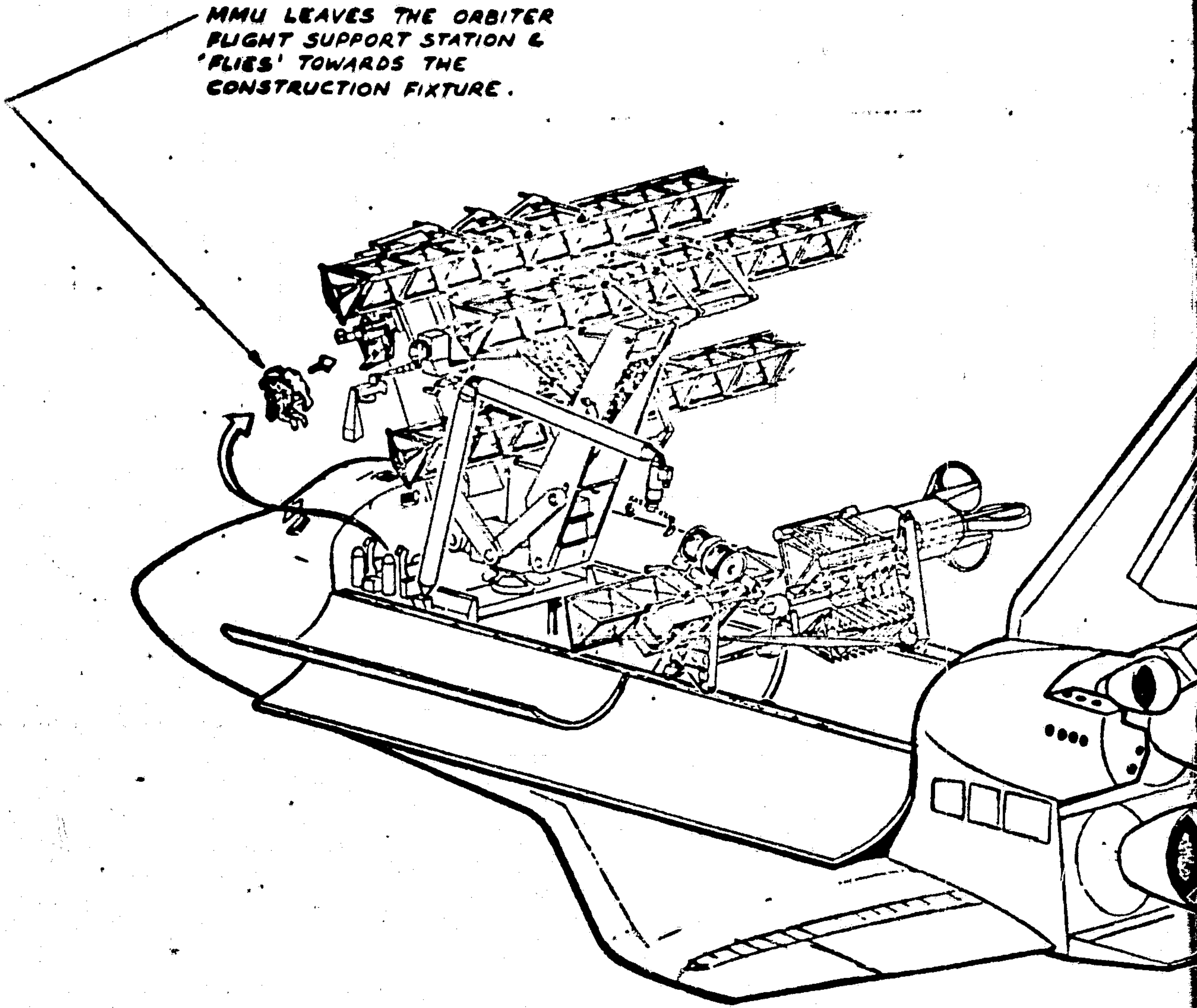
(2) MMU LOCKED IN ATTACHMENT STATION

5 FOLDOUT FRAME



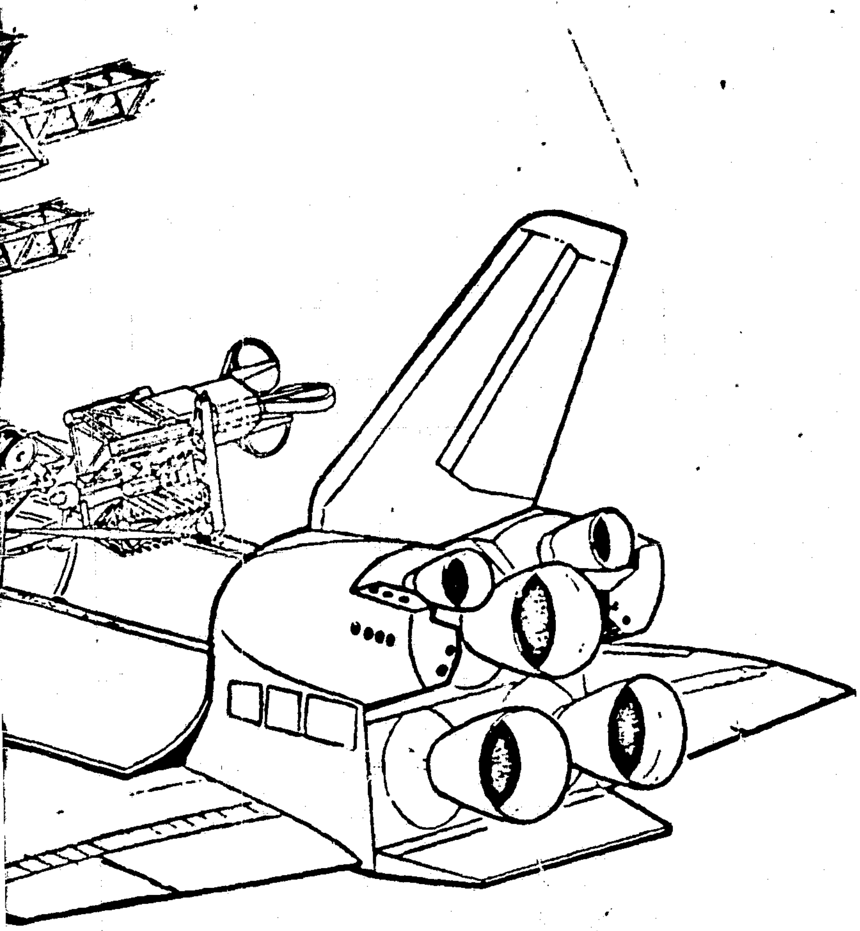
(1) MMU MANEUVERING TOWARDS ATTACHMENT STATION

7 FOLDOUT FRAME



TRANSLATION OF ASTRONAUT VIA MMU FROM ORBITER TO CONSTRUCTI

8 FOLDOUT FRAME



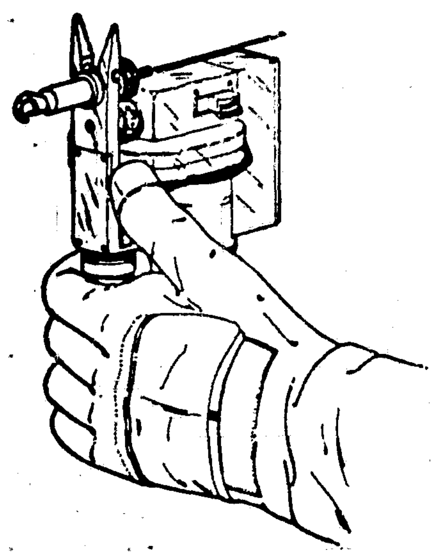
BITER TO CONSTRUCTION FIXTURE

A-63,
A-64

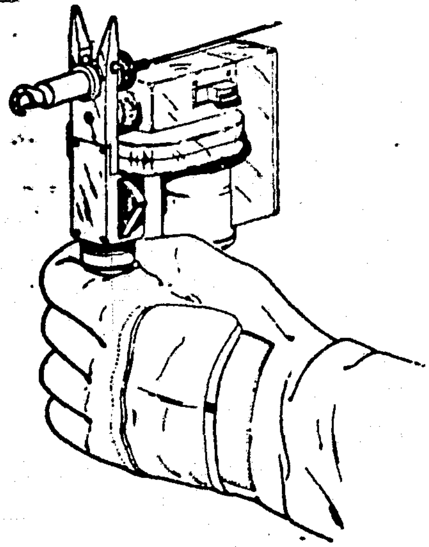
Rockwell International

EVA WORK STATION FUNCTIONS - DESCRIPTION & ILLUSTRATION	42662-78 SHEET 1 OF 3

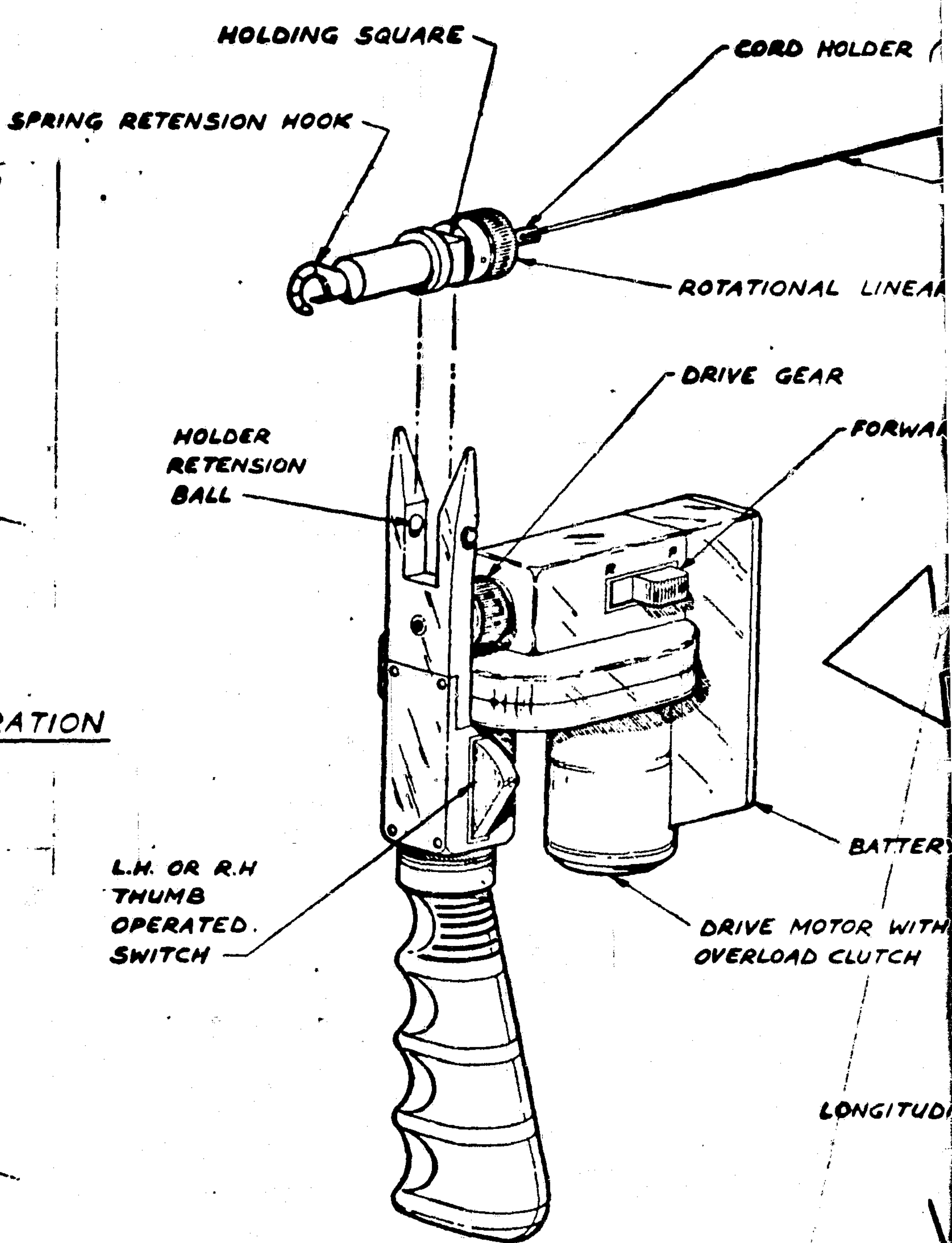
FOLDOUT FRAME



CORD TENSIONING OPERATION



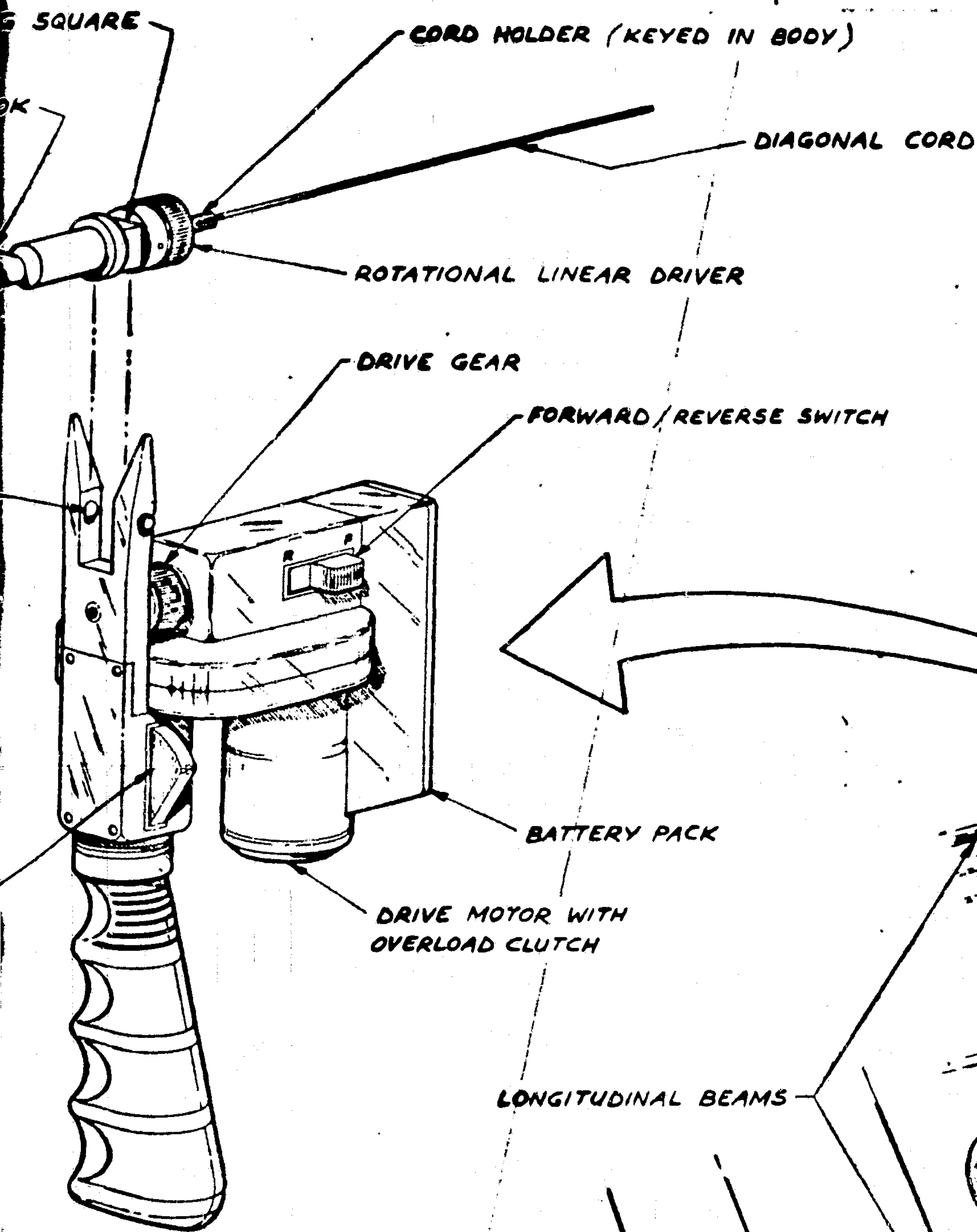
DEVICE IN POSITION



HAND HELD CORD TENSIONING DEVICE

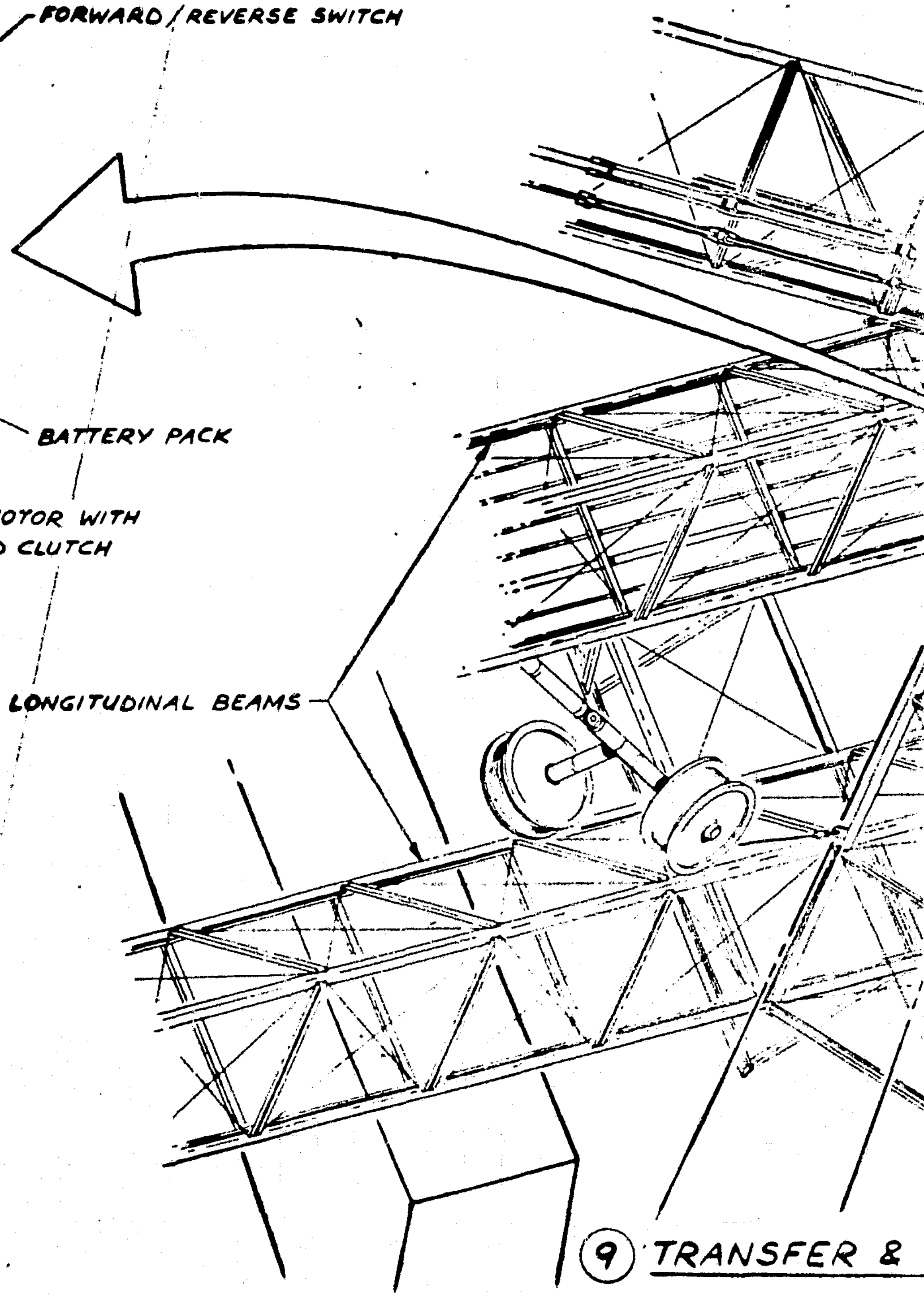
NOTE - AFTER DIAGONAL CORD HAS BEEN ASSEMBLED HAND HELD DEVICE IS USED, AS SHOWN, TO TENSION CORD (VIA, LEADING HOOK) TO PRE-DETERMINED AMOUNT.

2 FOLDOUT FRAME



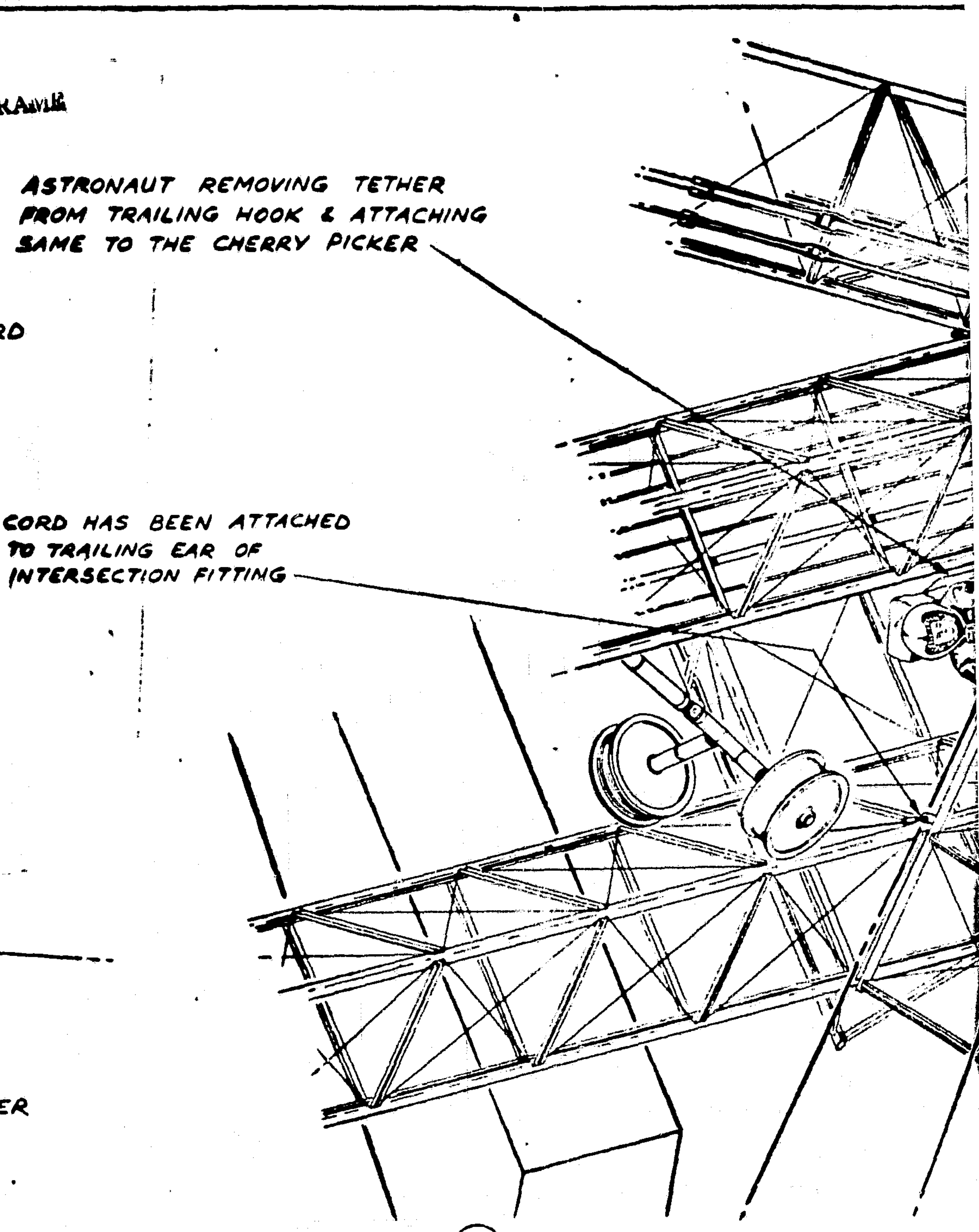
IAND HELD CORD
'ENSIONING DEVICE

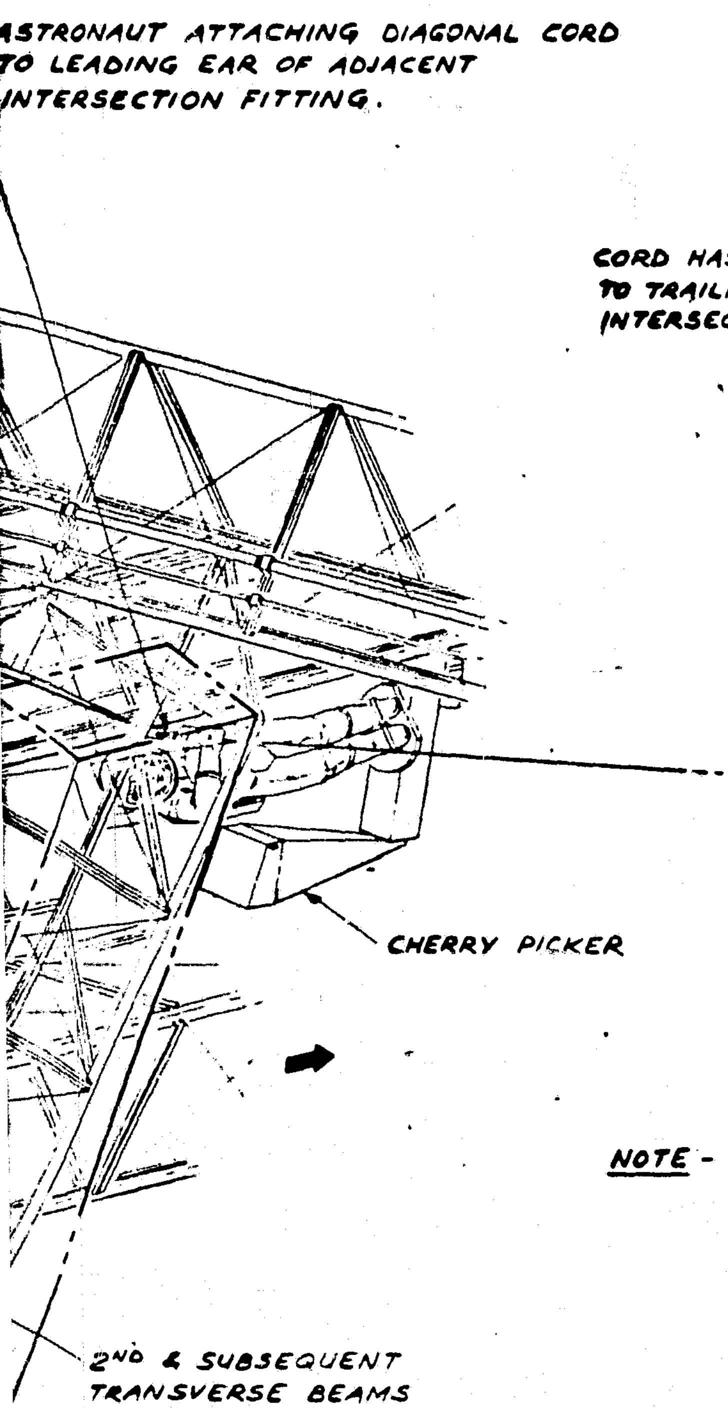
3LED
TENSION
'ED AMOUNT.



(9) TRANSFER &

3 FOLDOUT FRAME





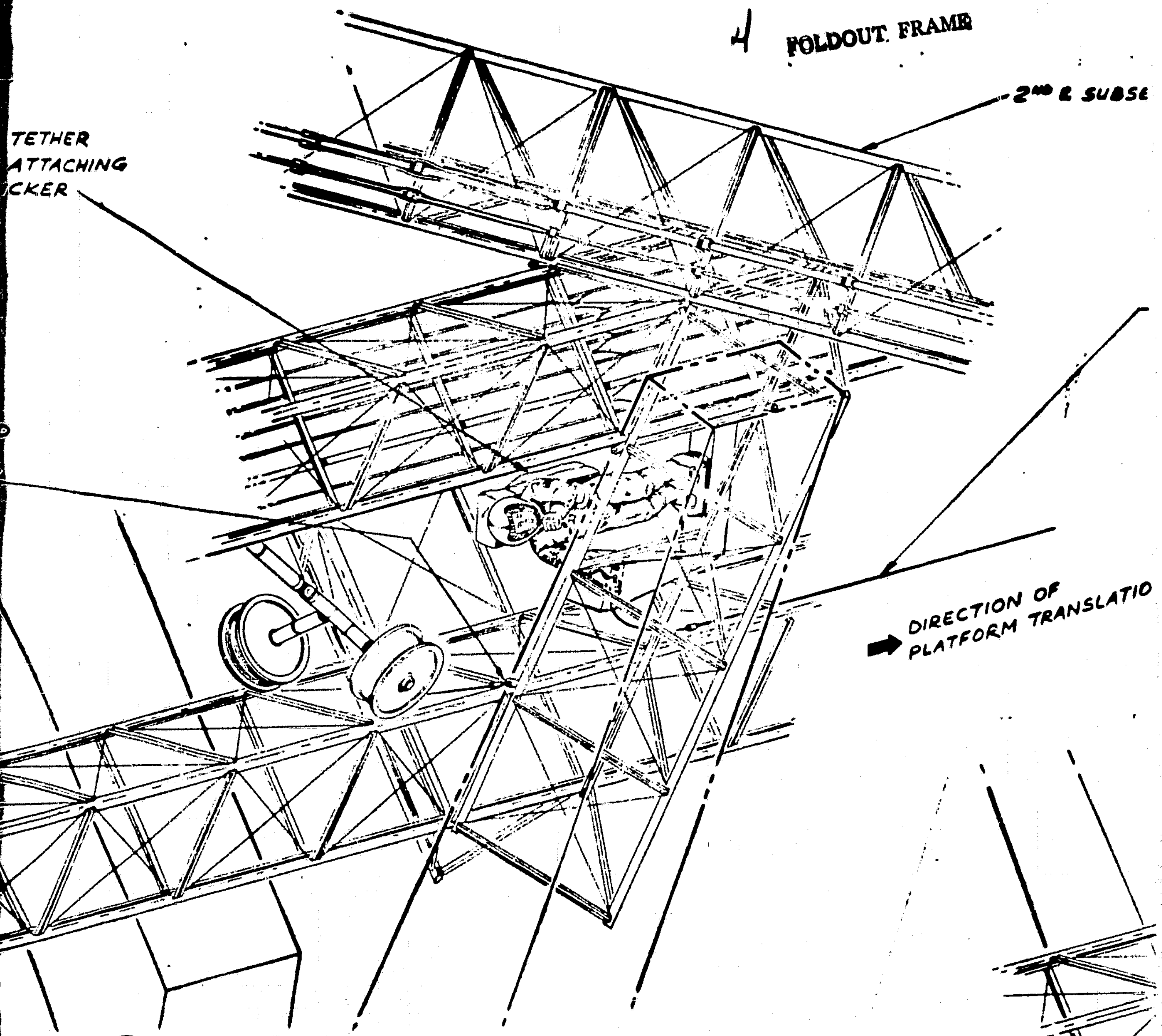
(8) DECOUPLING OF DIAGONA

NOTE -
- AT THE 2ND & SUBSEQUENT BEAM INTERSECTIONS THE ASTR TRAILING HOOK ON THE CORD TO THE TRAILING EAR OF THE
- THE TETHER ATTACHED TO THE TRAILING CORD HOOK IS R TO AN ATTACHMENT PROVIDED ON THE CHERRY PICKER.
- THE CHERRY PICKER IS ROTATED TO THE ADJACENT BEAM THE ASTRONAUT ATTACHES THE LEADING HOOK TO THE L INTERSECTION FITTING.
- THE TETHER IS REMOVED FROM THE LEADING CORD HOO REPEATED, CROSSING THE CORDS. (TYP. FOR ALL 3 SIDE

FOOT NOTE: AN ALTERNATE TO INDIVIDUAL TETHERS WOUL ATTACHMENT WITH A DOUBLE ENDED TETHER PERMENTLY AT

CH OF DIAGONAL CORD

4 FOLDOUT FRAME



(8) DECOUPLING OF DIAGONAL CORD

SUBSEQUENT BEAM INTERSECTIONS THE ASTRONAUT ATTACHES THE
OK ON THE CORD TO THE TRAILING EAR OF THE INTERSECTION FITTING.

ATTACHED TO THE TRAILING CORD HOOK IS REMOVED & SECURED
HMENT PROVIDED ON THE CHERRY PICKER.

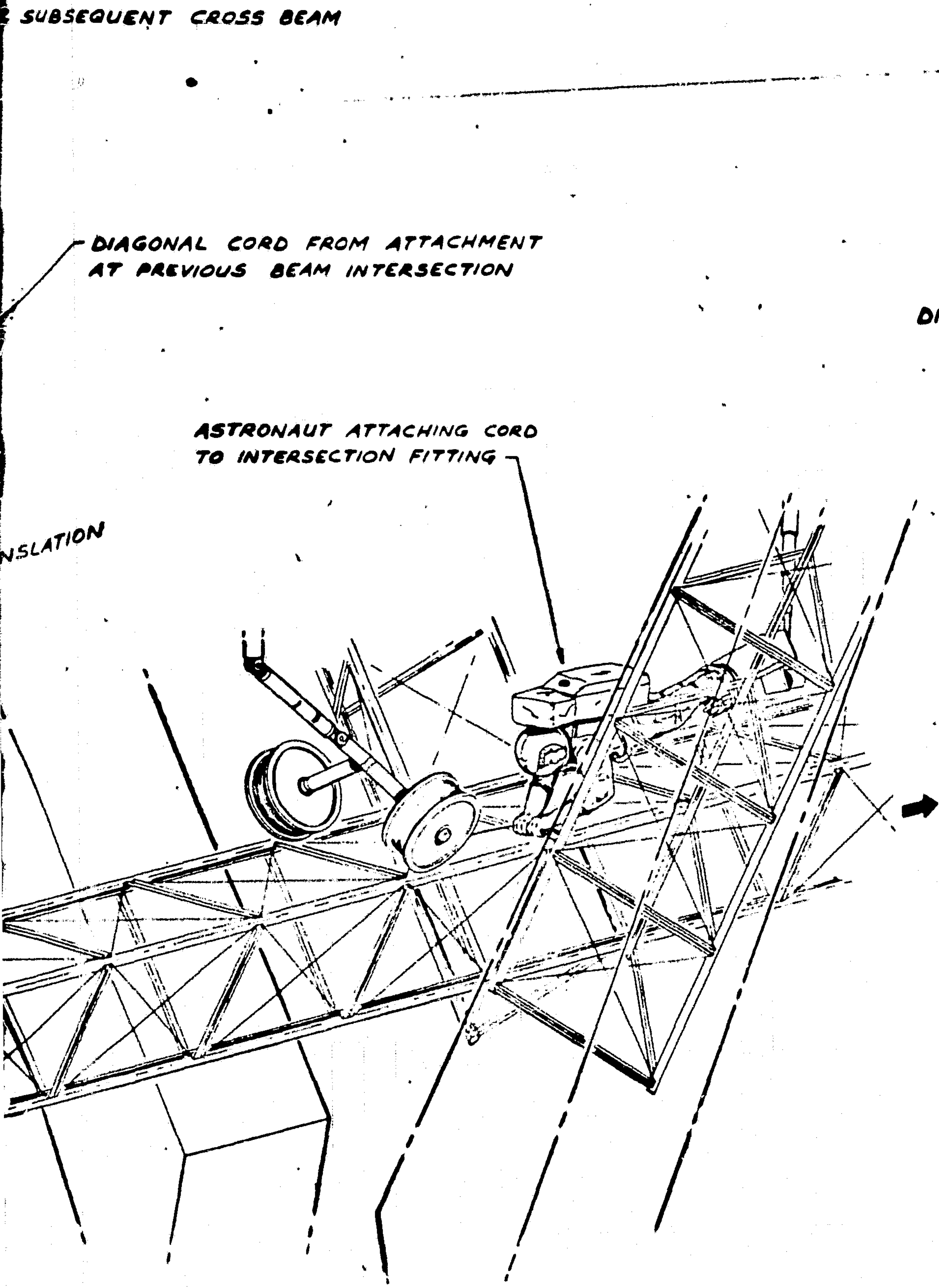
PICKER IS ROTATED TO THE ADJACENT BEAM INTERSECTION WHERE
AUT ATTACHES THE LEADING HOOK TO THE LEADING EAR OF THE
N FITTING.

IS REMOVED FROM THE LEADING CORD HOOK & THE PROCEDURE
CROSSING THE CORDS. (TYP. FOR ALL 3 SIDES OF THE PLATFORM.)

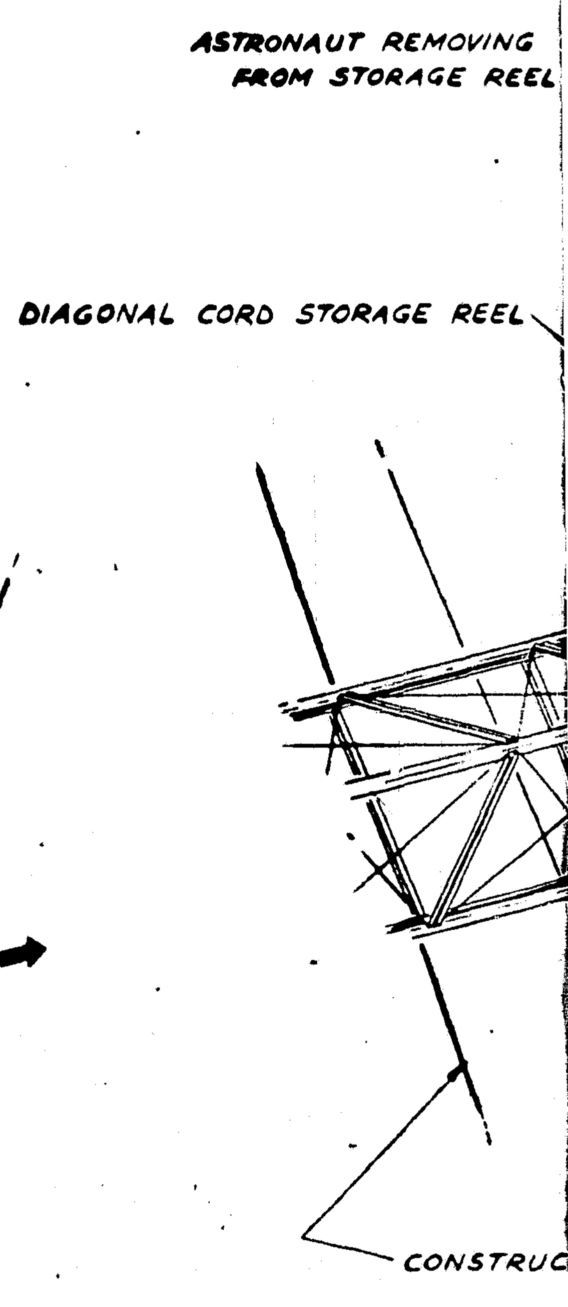
AN ALTERNATE TO INDIVIDUAL TETHERS WOULD BE A CORD HOOK TO HOOK
T WITH A DOUBLE ENDED TETHER PERMENTLY ATTACHED TO THE CHERRY PICKER.

(7) IN

5 FOLDOUT FRAME

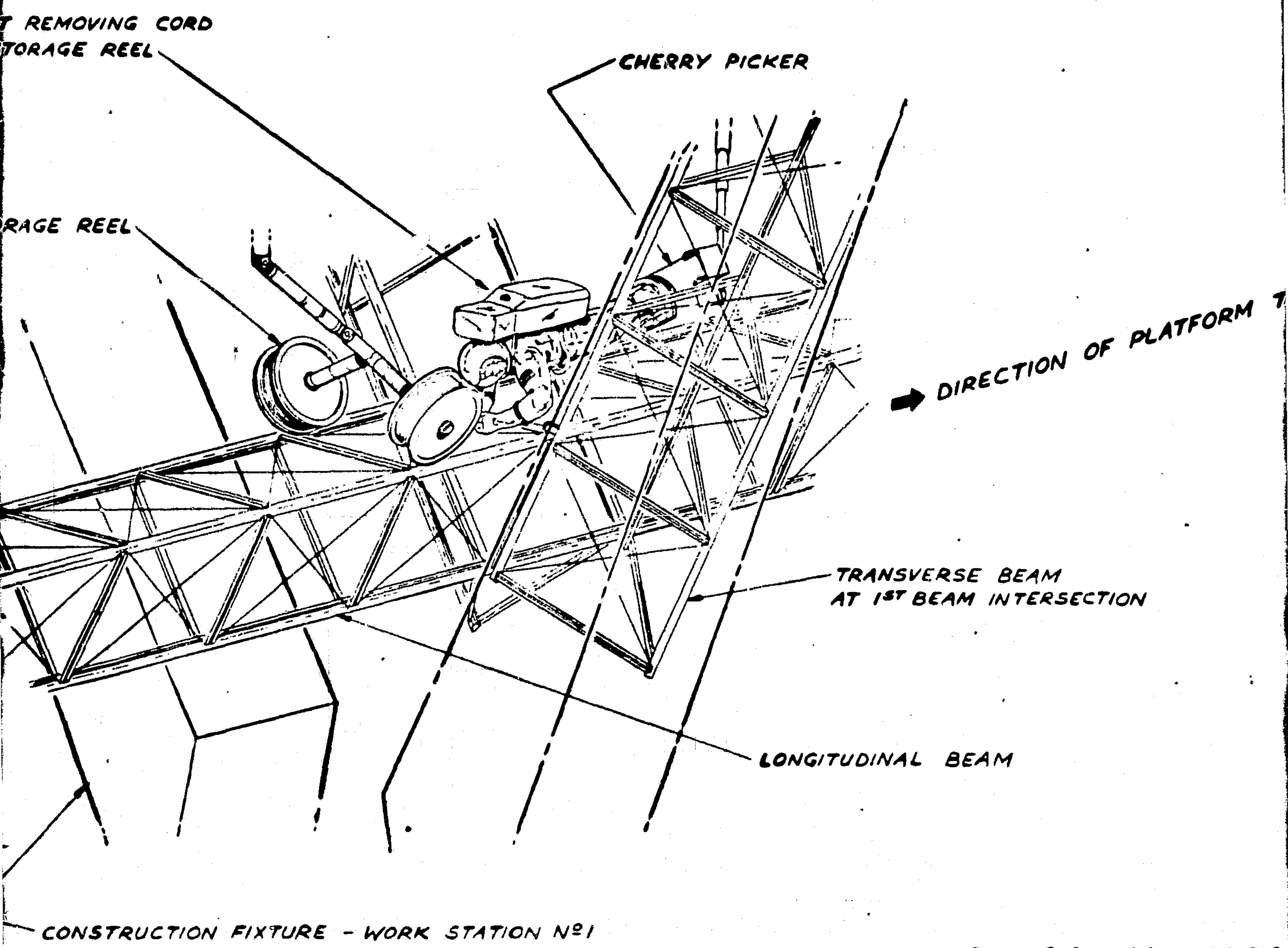


7) INITIAL DIAGONAL CORD ATTACHMENT



6) INITIAL DIAGON

NOTE -
- AT THE FIR
THE CORD EN
TRAILING E
- ABOVE PRO
INTERSECTIO



DIAGONAL CORD

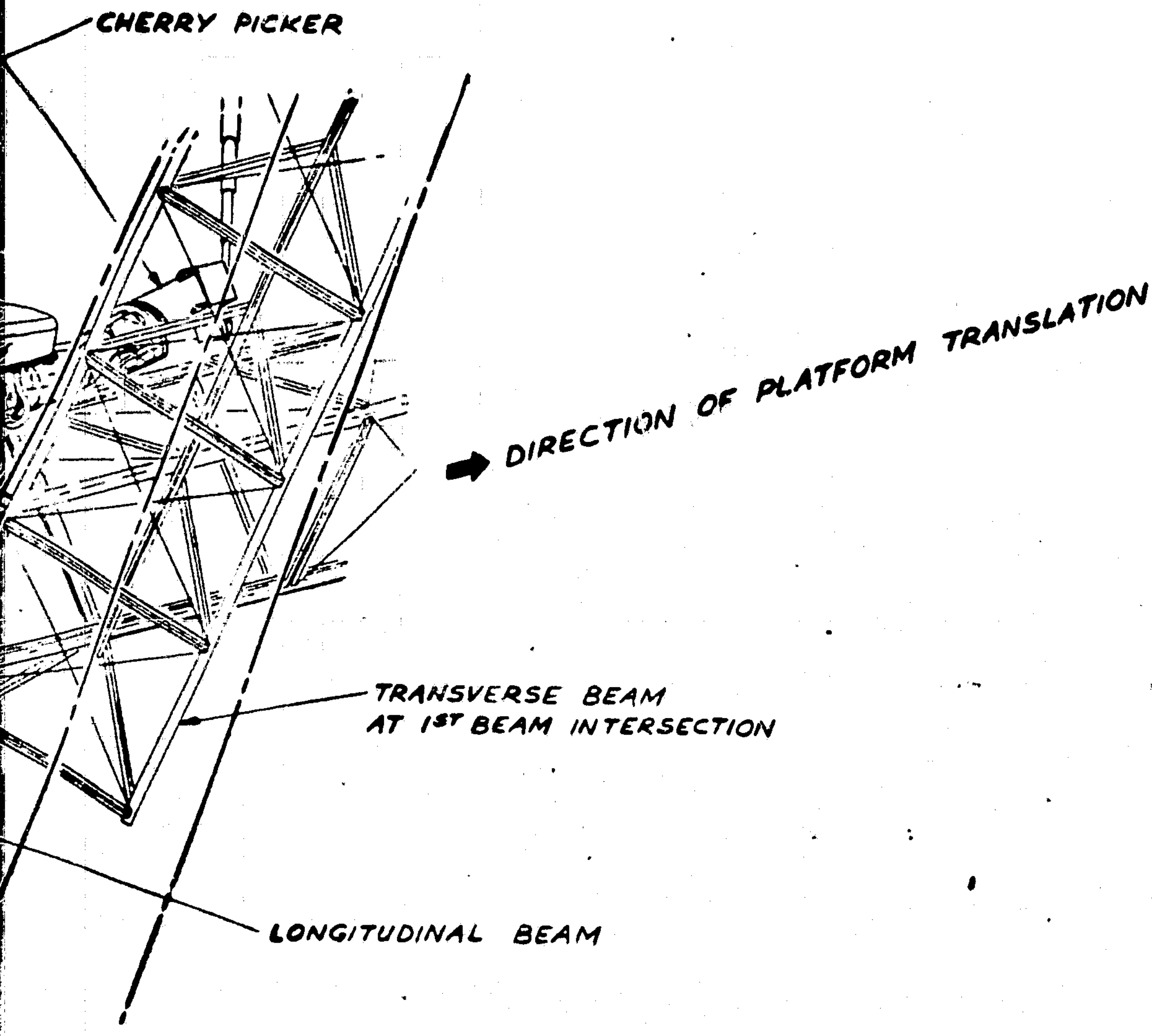
IL DIAGONAL CORD REMOVAL FROM REEL

- AT THE FIRST BEAM INTERSECTION ASTRONAUT REMOVES THE CORD END FROM REEL AND ATTACHES SAME TO THE TRAILING EAR OF THE INTERSECTION FITTING.
- ABOVE PROCEDURE REPEATED AT EACH BEAM TO BEAM INTERSECTION (TOTAL 6 PLACES)

EVA

- DES

1 FOLDOUT FRAME



Nº1

DIAGONAL CORD INSTALLATION

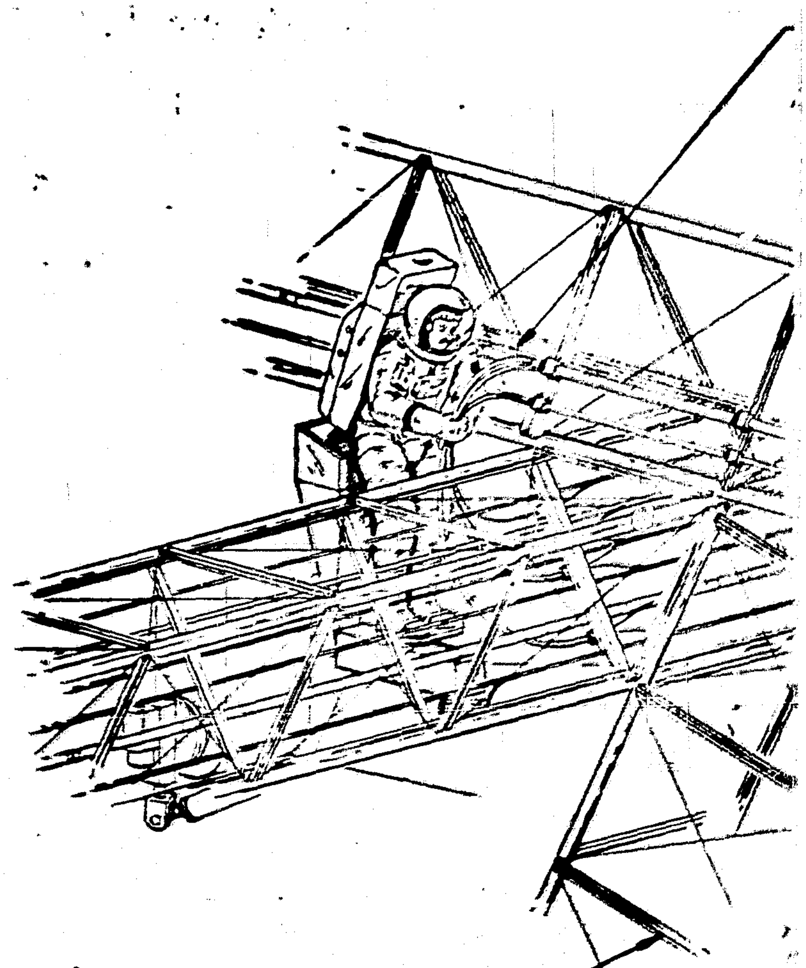
M REEL

T REMOVES
TO THE

TO BEAM

A-65,
A-66

—	BUCK/FAY 2/12/80 SCSA	Rockwell International	
EVA WORK STATION FUNCTIONS - DESCRIPTION & ILLUSTRATION			42662-78 SHEET 2 OF 3



(12) PIGTAILS SECURED TO STRUCTUR

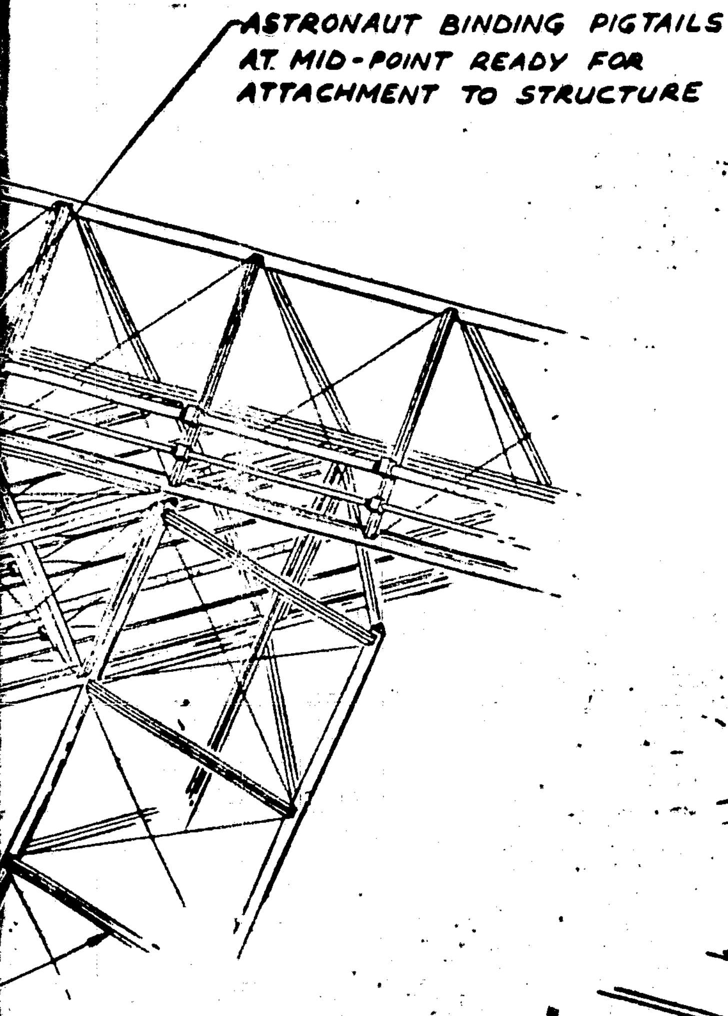
NOTE –

- ASTRONAUT REMOVES TIES ON CROSS BEAM, FR
THE PIGTAIL CABLES.

- PIGTAIL ENDS ARE TRANSFERED TO THE LONGITU
BEAM WHERE THE CONNECTOR END IS MATED WI
THE LONGITUDINAL BEAM CONNECTOR.

- THE PIGTAILS ARE BOUND TOGETHER AT THEIR
MID-POINT VIA., A VELCRO STRAP (OR SIMILAR
IS THEN WRAPPED AROUND AND SECURED TO TH
PLATFORM STRUCTURE.

FOLDOUT FRAME

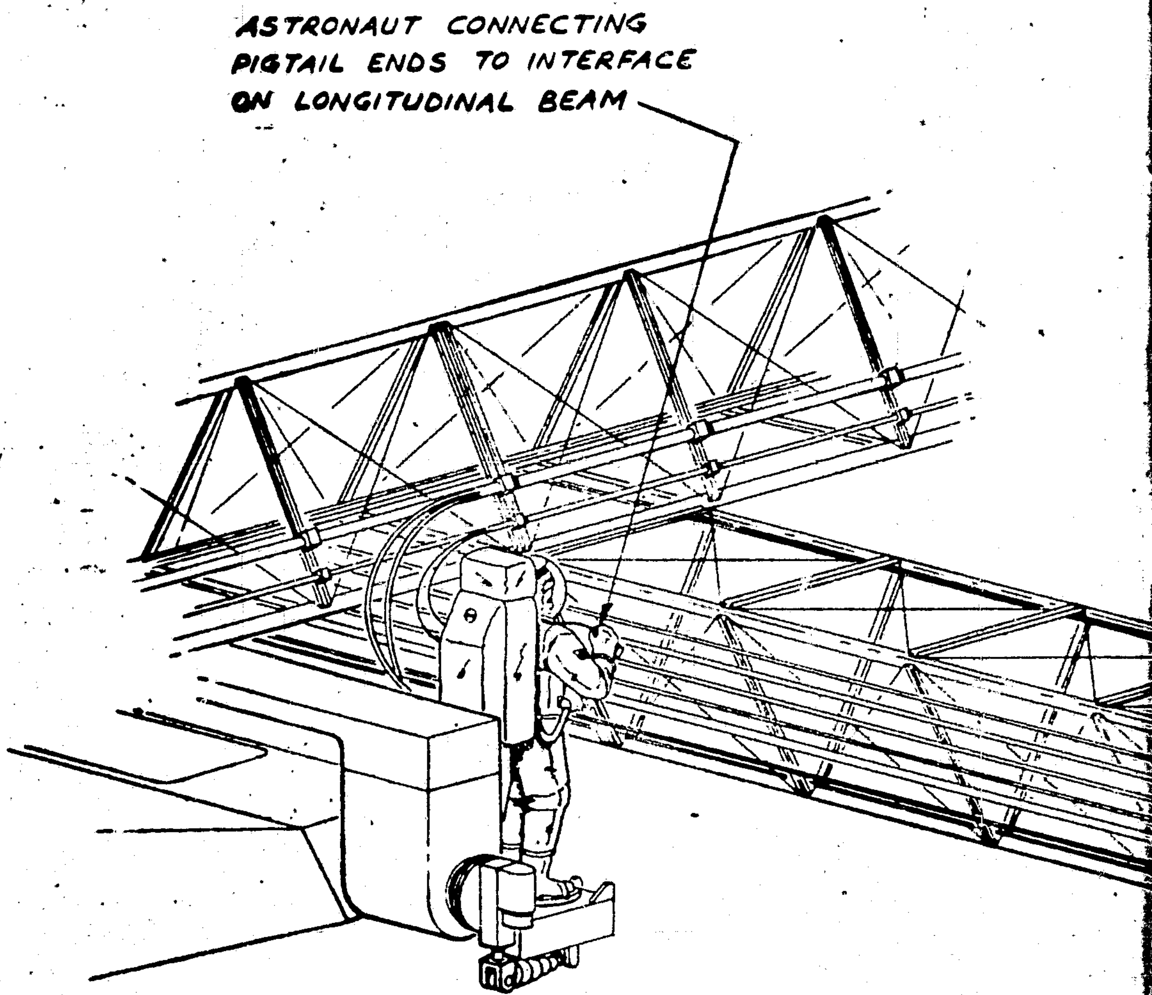


O STRUCTURE

ROSS BEAM, FREEING

O THE LONGITUDINAL
) IS MATED WITH
CTOR.

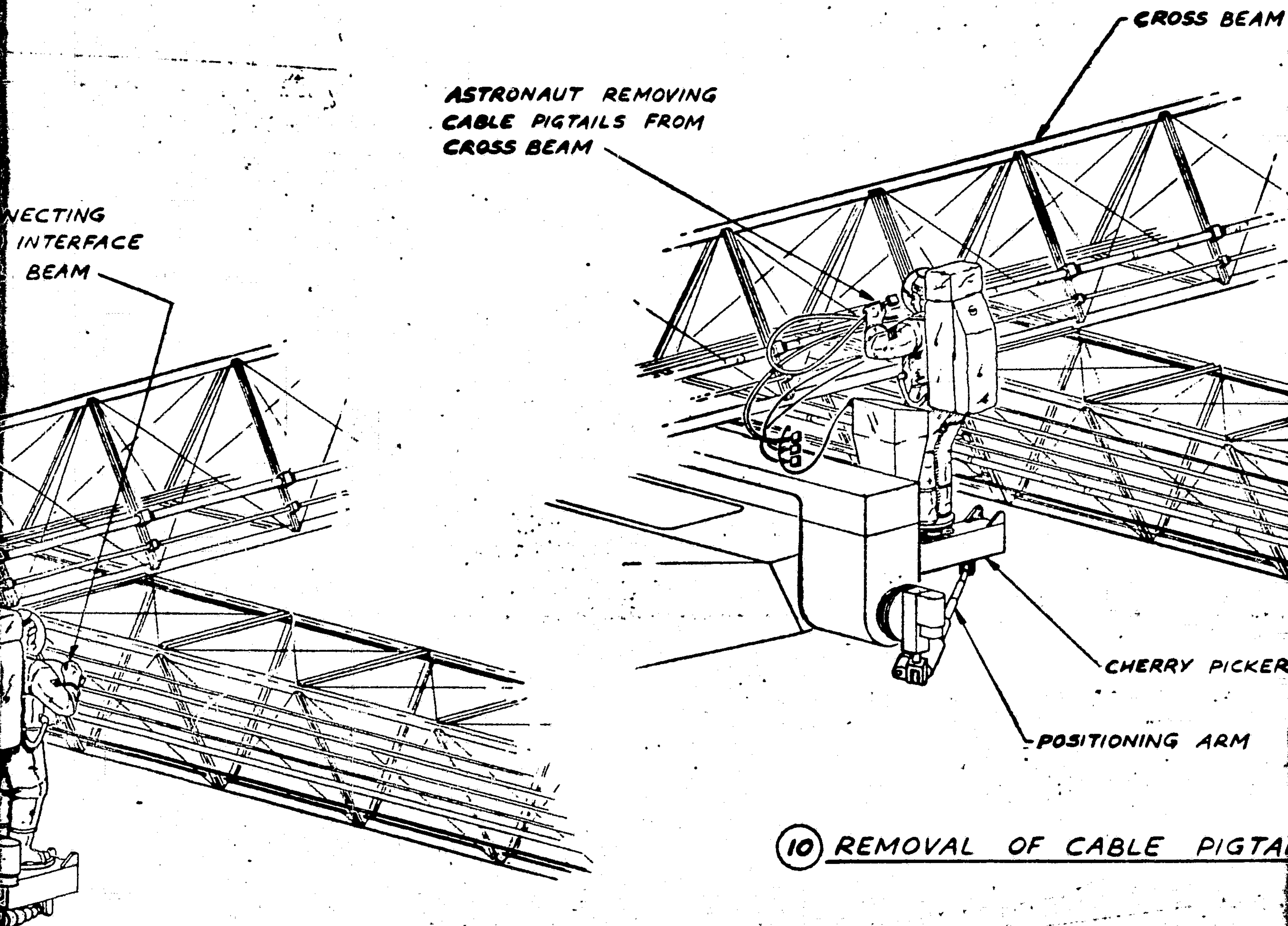
IER AT THEIR APPROX.
) (OR SIMILAR) WHICH
ECURED TO THE



(11) CABLE INTERFACE CONNECTION

ELECTRICAL CABLE

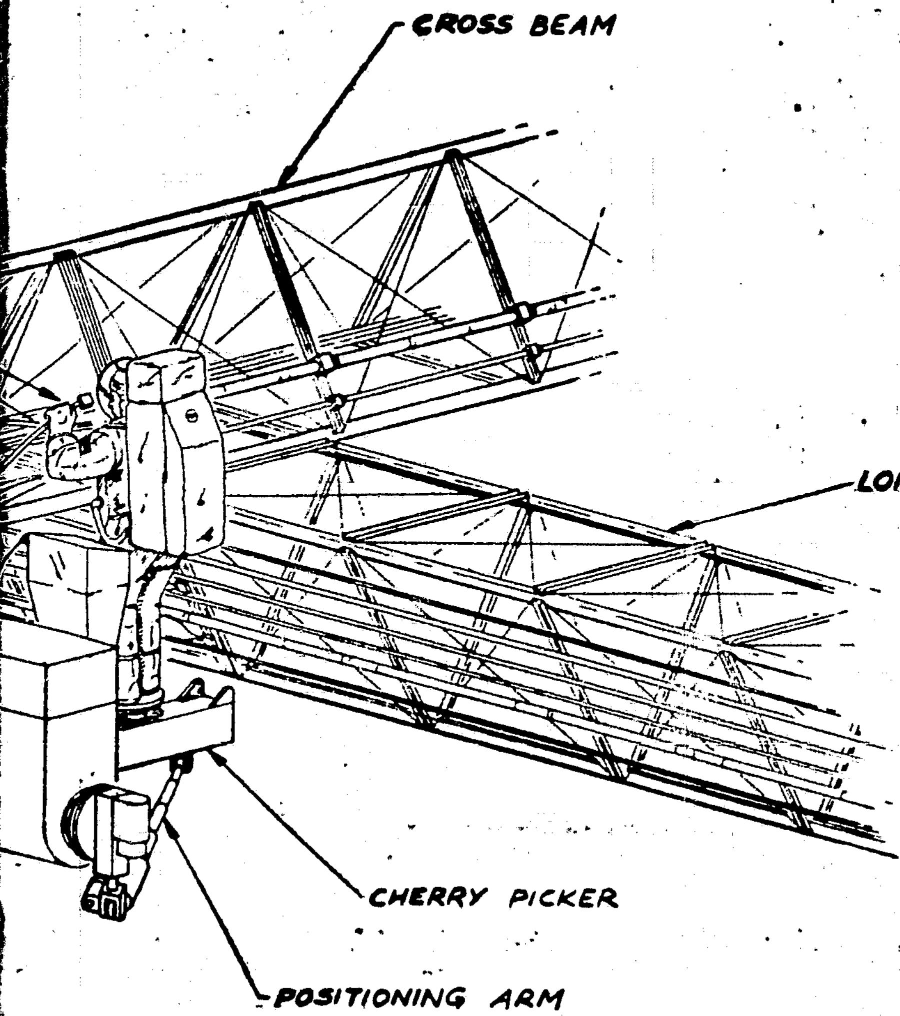
3 FOLDOUT FRAME



TERFACE CONNECTION

(10) REMOVAL OF CABLE PIGTAI

ELECTRICAL CABLE INTERFACE CONNECTION PROCEEDURE



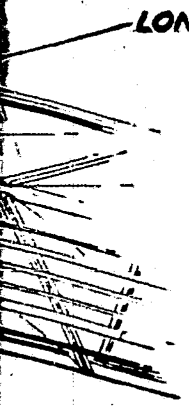
REMOVAL OF CABLE PIGTAILS

NECTION PROCEEDURE

A
A

BUCK/FRY 2/12/80 SC54	Rockwell International		
EVA WORK STATION FUNCTIONS - DESCRIPTION & ILLUSTRATION			426 SHEET

6 FOLDOUT FRAME



A-67,
A-68

BUCK/FRY 2/12/80 SC54	Rockwell International	
EVA WORK STATION FUNCTIONS - DESCRIPTION & ILLUSTRATION		42662-78 SHEET 3 OF 3

APPENDIX B

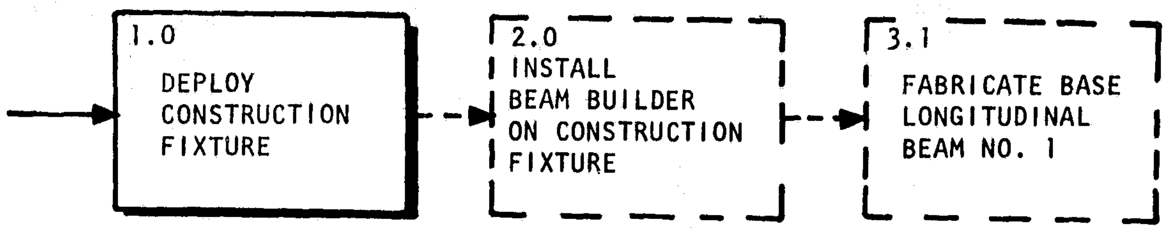
CONSTRUCTION ACTIVITY DATA SHEETS AND SUPPORTING DATA PACKAGES

The following material is formally documented results of analyses of specific construction activities identified during the study of design and construction of an Engineering and Technology Verification Platform (ETVP). The sheets are arranged in numerical order, and represent analytical effort performed for three successive missions. Mission 1 analyses begin with No. 1.0 and continue through No. 17.2. Mission 2 analyses begin with No. 21.0, and Mission 3 analyses begin with No. 41.0. A total of 43 separate packages of data is included.

ACTIVITY 1.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT: ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM



REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-50 Construction Fixture
3. Drawing 42662-64 Modifications to Beam Builder
4. Drawing 42662-66 Orbiter Stowage and Return, First Flight

DESCRIPTION OF ACTIVITY

Following checkout of the RMS, the construction fixture (described in Attachment No. 1) is removed by the RMS from the orbiter bay, rotated, and mated to the elevated docking interface of the orbiter. Remotely actuated connectors will complete the electrical interface. The various subsystems of the fixture are deployed remotely at astronaut command initiated from the orbiter crew cabin. Subsequent to checkout and installation of the beam builder, the fixture is ready to fabricate the first longitudinal beam. Selected aspects of the deployment are illustrated in Attachment 3.

CONSTRUCTION SUPPORT EQUIPMENT: RMS, lighting, and TV

TIMELINE

- 86 minutes, 30 seconds to erect, deploy, and check out the fixture (see Attachment No. 2 and Section 5.3)

POWER/ENERGY

- Average power, 0.665 kW; peak power, 2.4 kW; energy, 3450 kJ. (See Attachment 2 and Section 5.3)

CREW LOAD

- IVA: One man, continuous
- EVA: 0

TECHNOLOGY DEVELOPMENT REQUIREMENTS

- None required for the activity.

PREPARED BY: R. HART	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 2
CHECKED BY:		ACTIVITY 1.0
DATE: 21 NOV 1979	ERECT AND DEPLOY CONSTRUCTION FIXTURE	MODEL NO. ETVP
SHEET NO.	ATTACHMENT NO. 1	DWG. NO. REF: 42662-50

Construction fixture is shown on Drawing 42662-50, Sheets 1 through 4.

1 The installed orientation of the construction fixture on the orbiter and an early conceptual concept of fixture assembly are presented. Sheet 4 illustrates the revised current construction fixture concept.

2 Shows the addition of the attach port magazine and welder to the beam machine. Conceptual details of the intersection fitting used to structurally join the crossbeams to the longitudinal beams are shown in Zone 30. In Zones 40 through 43 the approach for installing the electrical lines from the cable storage reels is illustrated.

3 Shows the addition of the arms supporting the libration damping RCS, together with the associated black boxes, batteries, antennas, etc.

4 Illustrates the latest concept for the construction fixture system which supersedes the initial building block approach. The new system is basically self-contained and involves extensive deployment of the principal elements. The advantages of the new system are:

- Reduced crew workload
- Reduced time to configure system for operation
- Frees the RMS for other activities
- The complete assembly can be checked out on the ground
- Reduces the number of electrical and mechanical interfaces

The disadvantage of the deployable system is its increased cost because of the mechanical complexity.

The construction fixture consists of the following items:

- Yoke structure
- Rigidizing links
- Folding bridge structure
- Folding bridge structure separation latches
- Libration damping RCS, gyros, electronics, and articulated arms
- Batteries
- Omni antennas
- Navigation lights
- Beam builder interface, elec. and mech.
- Crossbeam positioner
- Platform drive rollers and extending support artms
- Six cross-brace cable reels, deployment arms, and all cross-brace cables
- Electric cable laying machine, deployment mechanism and all electric cables for longitudinal beam
- Cherry picker and maneuvering arm
- Attach points for MMU and contingency equipment
- Work lights and TV
- Attach points for RMS
- Emergency EVA handholds, footholds, etc.
- Orbiter attachments (stowage)

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 2 OF 2
CHECKED BY:		ACTIVITY 1.0
DATE:	ERECT AND DEPLOY CONSTRUCTION FIXTURE	MODEL NO. ETVP
SHEET NO.	ATTACHMENT NO. 1 (CONT.)	DWG. NO. REF: 42662-50

The deployment of the various subsystems of one construction fixture is controlled from the orbiter crew cabin. All of the motions required to translate, rotate, lock, unlock, etc., are powered by motors built into the system and initiated by an astronaut in the orbiter crew cabin. Feedback information is supplied to the controller to verify completion of functions.

The beam builder interface with the construction fixture is identical to that on the No. 2 construction station.

The cherry picker and maneuvering arm are rotated to a central position when not in use.

The cross-brace cable reels are retained in the stowed position when not in use. One of the reels is moved to the semi-stowed position when the electrical cable-laying machine is deployed. The reels are not power driven. The reels provide a controlled drag force to tension the cables during installation.

The electric cable-laying machine is retained in the stowed position when not in use. The reel dispenses the 108-meter harness, which runs the length of one of the longitudinals. The harness is attached to each beam crossmember by means of a Velcro strip. The harness is complete with breakout pigtails and connectors for manual connection to the crossbeam harnesses, to the control module and to the propulsion systems.

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OF POOR QUALITY

ACTIVITY 1.0

ATTACHMENT 2

TIME, POWER, & ENERGY ESTIMATION FOR ERECTION, DEPLOYMENT AND CHECKOUT OF THE CONSTRUCTION FIXTURE

TASK DESCRIPTION	DURATION (SEC)	PEAK POWER (kW)	AVG POWER (kW)	ENERGY (KJ)
NOTE: THE FIRST SECTION OF THIS TABLE DEALS ONLY WITH THE ERECTION & DEPLOYMENT OF THE CONSTRUCTION FIXTURE.				
1. GRASP THE CONSTRUCTION FIXTURE WITH THE RMS	60	0.845 (a) 1.050 (b)	0.845 1.050	50.7 63.0
2. RELEASE THE PAYLOAD RETENTION LATCHES	30	0.02	0.02	6
3. USE THE RMS TO REMOVE THE CONSTRUCTION FIXTURE FROM THE ORBITER BAY AND RAISE IT TO A POSITION IN LINE WITH THE DOCKING FIXTURE IN THE ORBITER BAY	600	0.845 (a) 1.050 (b)	0.845 1.050	507 630
4. RAISE THE DOCKING FIXTURE TO ITS DEPLOYED POSITION	60	0.05	0.05	3
5. ROTATE THE CONSTRUCTION FIXTURE 90 DEGREES ABOUT ITS Z-AXIS	180	0.845 (a) 1.050 (b)	0.845 1.050	152.1 189
6. MATE THE CONSTRUCTION FIXTURE TO THE DOCKING FIXTURE; OPERATE THE STRUCTURAL LATCHES AND THE ELECTRICAL INTERFACE CONNECTOR; THE CONSTRUCTION FIXTURE NOW HAS ELECTRICAL POWER; RELEASE THE RMS	600	0.845 (a) 1.050 (b) 0.10 (LATCHES)	0.845 1.050	507 630 (NEGL.)
7. EXPAND & RIGIDIZE THE YOKE (MAIN ARMS) OF THE CONSTR. FIXTURE; THE FOLDING BRIDGE STRUCTURE IS DEPLOYED BY THE ACTION OF THE YOKE	300	0.1	0.1	30
8. LOCK THE LINKS & HINGES OF YOKE & BRIDGE STRUCT.	30	0.02	0.02	0.6
9. ROTATE CENTER EXTENSION OF THE BRIDGE THROUGH 90 DEGREES & LOCK	90	0.02	0.02	1.8
10. EXTEND & LOCK THE 4 SUPPORT ARMS WHICH CARRY THE 27 BEAM DRIVE ROLLERS	90	0.08	0.08	7.2
11. TV, 120 W; TV HEATING, 24 W; LIGHTING 200 W FOR 1530 SECONDS (TASKS 1 THROUGH 10)	1530	0.344	0.344	526.3
TOTAL, ERECTION & DEPLOYMENT	2040	2.339*	1.703**	3298.3

(a) BASIC RMS (b) RMS HEATER

*SEE NOTE AT END OF THIS ATTACHMENT
**SEE NOTE AT END OF THIS ATTACHMENT

ATTACHMENT 2 (CONT.)

ACTIVITY 1.0

TASK DESCRIPTION	DURATION (SEC)	PEAK POWER (kW)	AVG POWER (kW)	ENERGY (KJ)
NOTE: THIS SECOND SECTION OF TABLE DEALS ONLY WITH THE CHECKOUT OF THE CONSTRUCTION FIXTURE PRIOR TO FABRICATION OF THE PLATFORM.				
12. ACTIVATE THE BEAM DRIVE ROLLERS FORWARD & REVERSE; 27 ROLLERS X 2 DIRECTIONS X 10 SEC EACH	270	0.01	0.01	2.7
13. ACTIVATE CHERRY PICKER AT WORK STATION NO. 1; USE EACH ARTICULATION IN SEQUENCE; 6 ARTICULATIONS X 60 SECONDS	360	0.1	0.1	36
14. STOW CHERRY PICKER IN A CENTRAL POSITION TO AVOID INTERFERENCE WITH BEAM BUILDER OPERATIONS	180	0.1	0.1	18
15. MOVE CROSS-BRACE CABLE REELS FROM THE STOWED TO THE DEPOLOYED POSITION & LOCK	120	0.05	0.05	6
16. MOVE ELECTRIC CABLE REEL FROM THE STOWED TO THE DEPLOYED POSITION & LOCK	60	0.05	0.05	3
17. RETURN THE ELECTRIC CABLE REEL TO THE STOWED POSITION & LOCK	60	0.05	0.05	3
18. RETURN THE CROSS-BRACE CABLE REELS TO THE STOWED POSITION & LOCK	120	0.05	0.05	6
19. CHECK OUT THE BEAM POSITIONER; MOVE EACH ARTICULATION (6 DEGREES OF FREEDOM); 6 ARTICULATIONS X 60 SEC—NOTE: THIS ALSO IS A CHECK FOR BEAM BUILDER ROTATION	360	0.05	0.05	18
20. DEPLOY & LOCK THE TWO ARTICULATED ARMS WHICH CARRY THE LIBRATION DAMPING RCS	180	0.05	0.05	9
21. CHECK OUT THE LIBRATION DAMPING RCS	300	0.001	0.001	0.3
22. RESTOW THE TWO ARTICULATED ARMS & LOCK	180	0.05	0.05	9

ATTACHMENT 2 (CONCL.)

ACTIVITY 1.0

TASK DESCRIPTION	DURATION (SEC)	PEAK POWER (kW)	AVG POWER (kW)	ENERGY (KJ)
23. TURN ON LIGHTS & TV FOR CHECKOUT—TV, 120 W; TV HEATING, 24 W; LIGHTING, 500 W	60	0.644	0.644	38.6
24. CHECK OUT BATTERIES	300	0.001	0.001	0.3
25. CHECK OUT BLACK BOXES	600	0.001	0.001	0.6
TOTAL, CHECKOUT	3150 52 MIN., 20 SEC	0.644*	0.048**	150.5
TOTAL, ERECTION & DEPLOYMENT	2040	2.339*	1.703**	3298.3
GRAND TOTAL	5190 86 MIN., 30 SEC	2.339*	0.665**	3448.8

*PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES SUBJECTIVELY ESTIMATED AS BEING PERFORMED SIMULTANEOUSLY.

**AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

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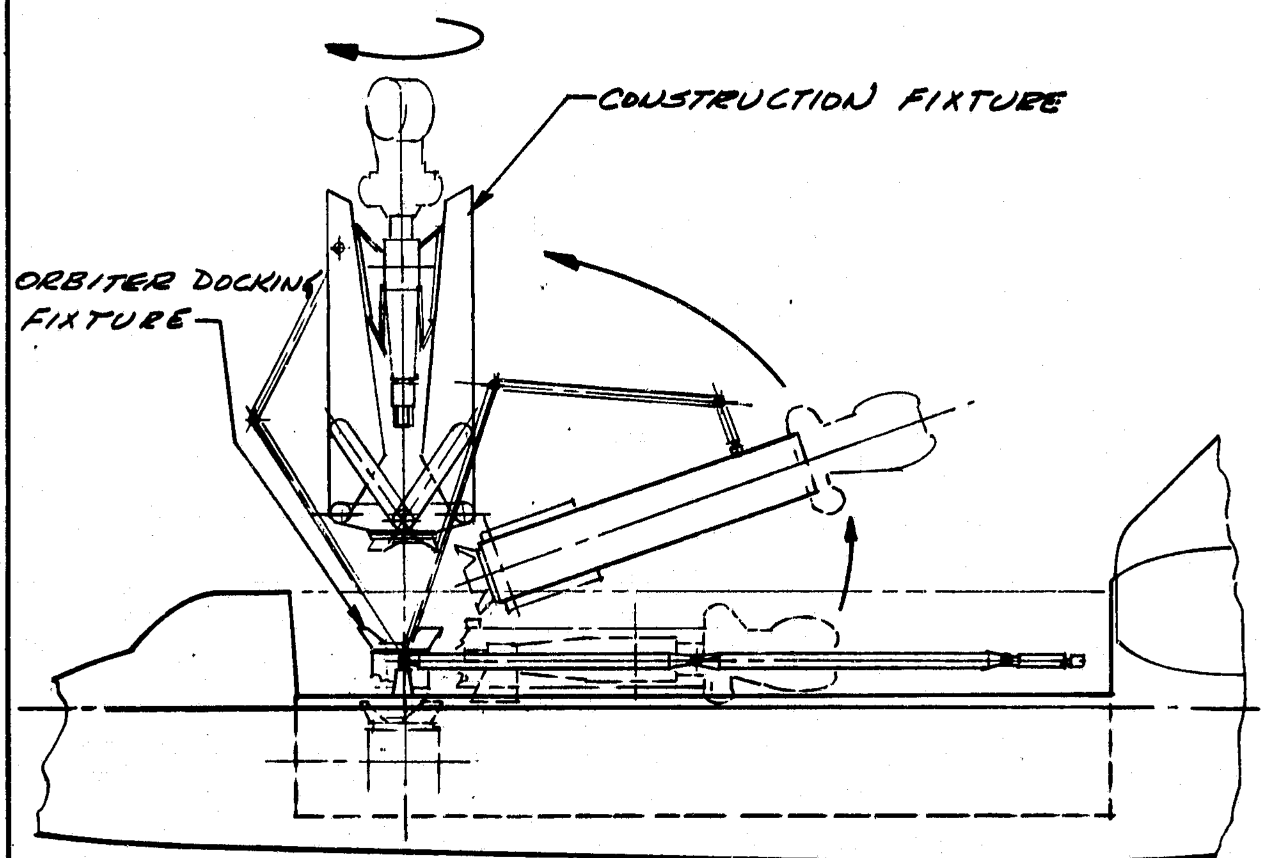
DATE:	ERECT & DEPLOY CONSTRUCTION FIXTURE	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT #3

- REMOVE THE CONSTRUCTION FIXTURE FROM THE ORBITER BAY
- RAISE THE ORBITER DOCKING FIXTURE
- ROTATE THE CONSTRUCTION FIXTURE
- MATE TO THE DOCKING FIXTURE



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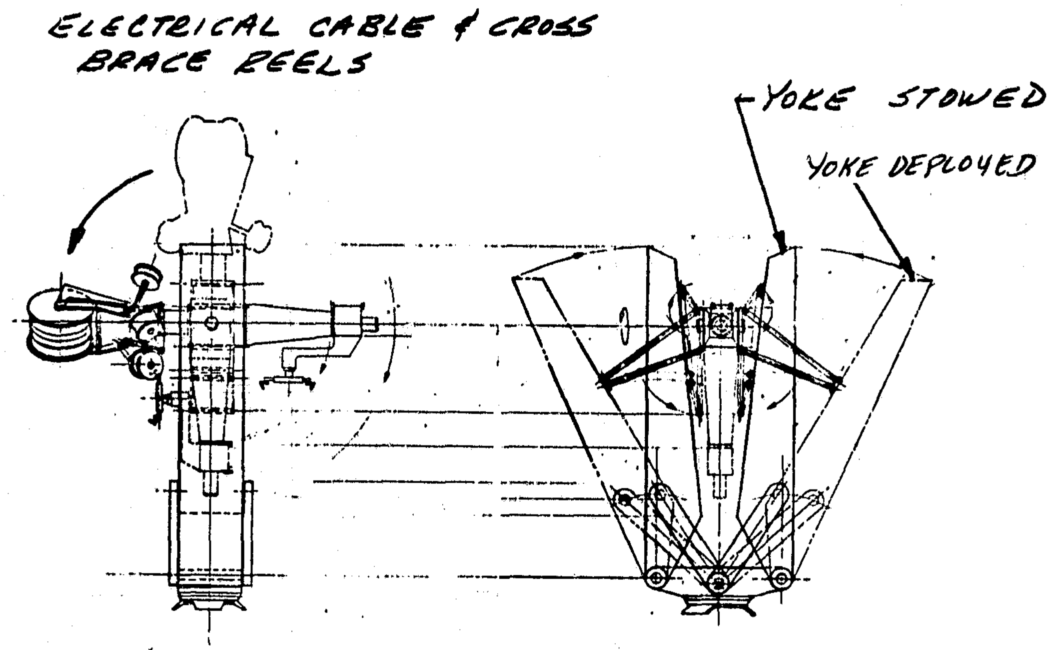
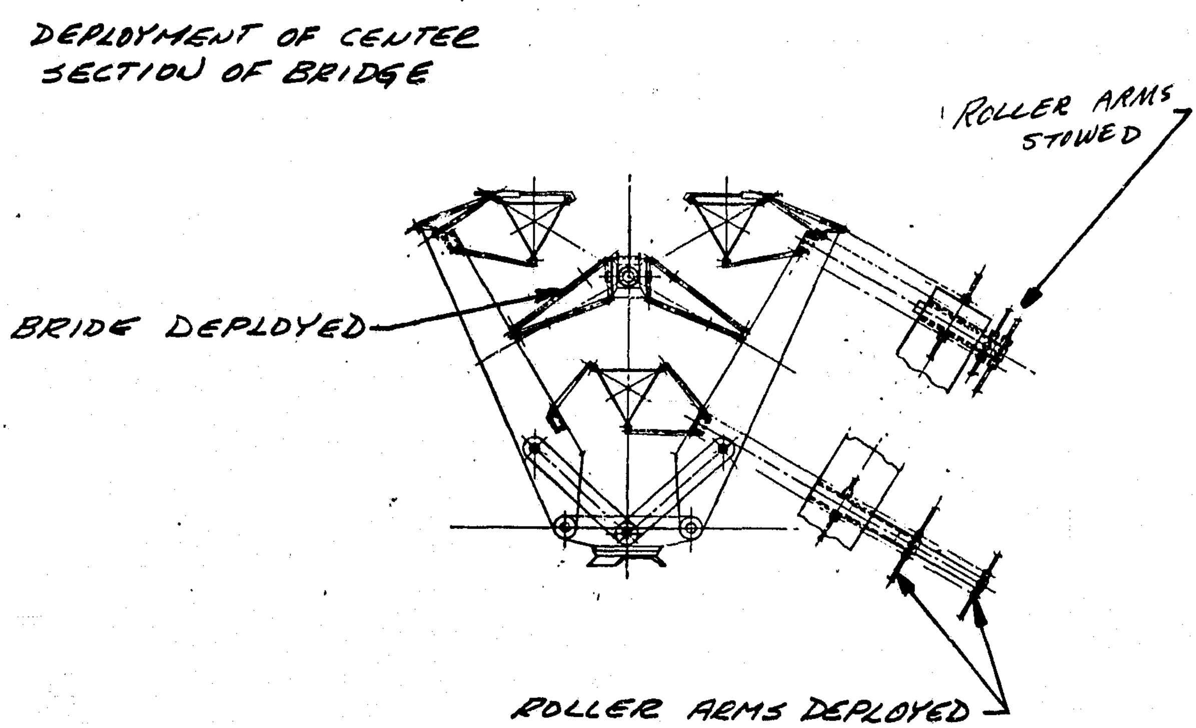
ATTACHMENT #3 (CONT'D)





NOTE:
LONGITUDINAL BEAMS SHOWN FOR REFERENCE ONLY

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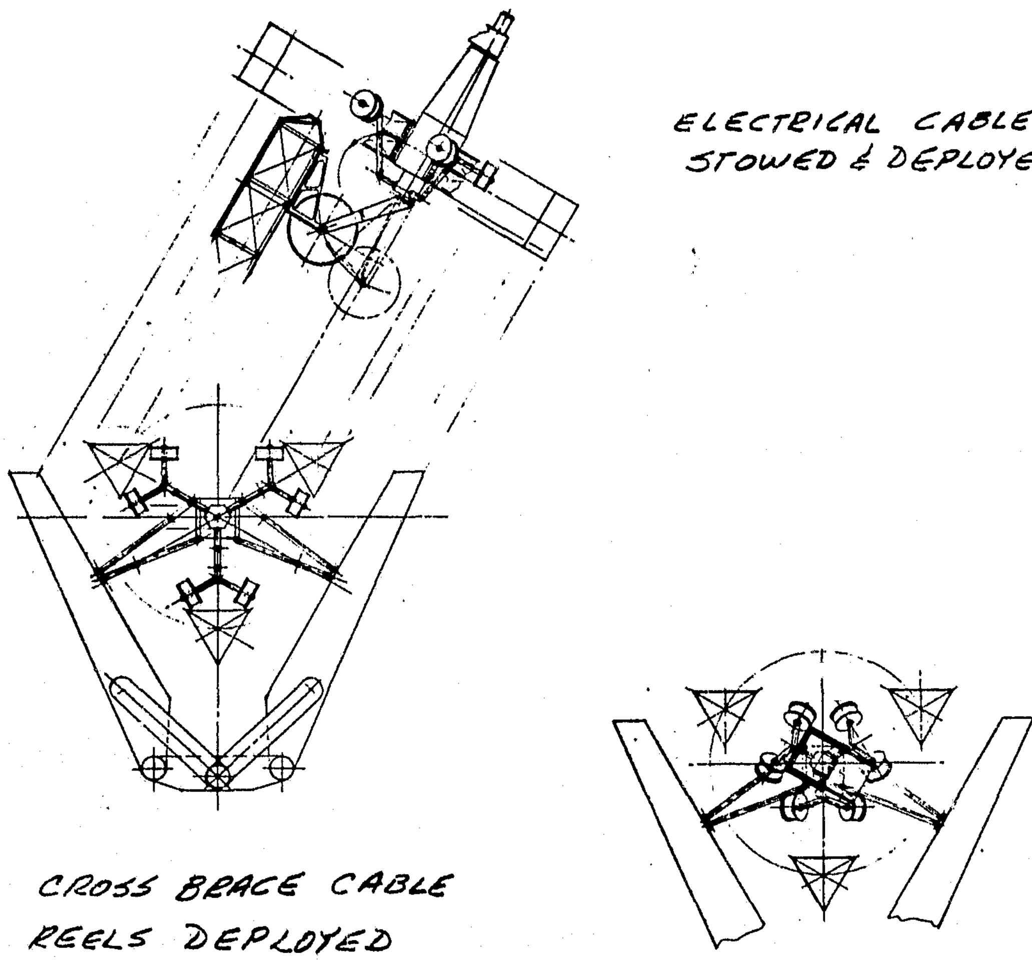
ATTACHMENT #3 (CONT'D)



ELECTRICAL CABLE REEL STOWED & DEPLOYED

CROSS BRACE CABLE REELS DEPLOYED

CROSS BRACE CABLE REELS STOWED

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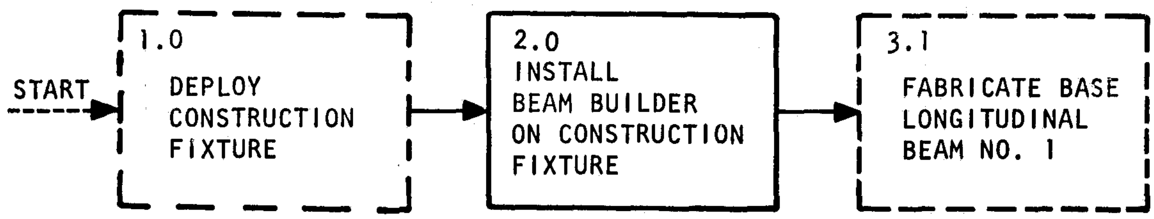
NOTE:
LONGITUDINAL BEAMS SHOWN FOR REFERENCE ONLY

FORM 994-B-1 REV 12-78

ACTIVITY 2.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT: ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM



REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-50 Construction Fixture
3. Drawing 42662-64 Modifications to Beam Builder
4. Drawing 42662-66 Orbiter Stowage and Return, First Flight

DESCRIPTION OF ACTIVITY

The beam builder assembly is removed by the RMS from the orbiter bay and installed on the construction fixture at the interface provided. The beam builder assembly (see Attachment 2) consists of:

- Magazine and six end attach ports
- Positioner and welder for the end attach ports
- Mechanical and electrical interface latches and connectors
- Beam builder
- Support tripod

CONSTRUCTION SUPPORT EQUIPMENT

- RMS
- Lighting
- TV
- Construction fixture

TIMELINE

1560 seconds (26 minutes)—see Attachment 1

POWER, ENERGY

Peak power, 2.2 kW; average power 1.53 kW; energy, 2374.7 kJ (see Attachment 1)

CREW LOAD

- IVA: One man, continuous
- EVA: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Electrical interface connector between fixture and beam builder assembly

ACTIVITY 2.0

ATTACHMENT 1

TIME, POWER, & ENERGY ESTIMATION FOR INSTALLING THE BEAM BUILDER ON CONSTRUCTION FIXTURE

TASK DESCRIPTION	DURATION (SEC)	PEAK POWER (kW)	AVG POWER (kW	ENERGY (KJ)
1. GRASP THE BEAM BUILDER ASSEMBLY WITH THE RMS	60	0.845 (a) 1.050 (b)	0.845 0.525	50.7 31.5
2. RELEASE THE PAYLOAD RETENTION LATCHES (REMOTE CONTROL FROM ORBITER CREW CABIN)	30	0.02	0.02	6
3. REMOVE THE BEAM BUILDER FROM THE ORBITER & TRANSPORT IT TO THE VICINITY OF THE FIXTURE	600	0.845 (a) 1.050 (b)	0.845 0.525	507 315
4. MATE THE BEAM BUILDER ASSEMBLY TO THE INTERFACE ON THE FIXTURE	600	0.845 (a) 1.050 (b)	0.845 0.525	507 315
5. SECURE THE MECHANICAL LATCHES BETWEEN THE BEAM BUILDER ASSEMBLY AND THE FIXTURE (REMOTE CONTROL FROM ORBITER CREW CABIN)	30	0.02	0.02	6
6. MATE THE ELECTRICAL INTERFACE CONNECTOR BETWEEN THE BEAM BUILDER ASSEMBLY AND THE FIXTURE (REMOTE CONTROL FROM ORBITER CREW CABIN)	30	0.02	0.02	6
7. RELEASE THE RMS & MOVE AWAY FROM THE FIXTURE/BEAM BUILDER ASSEMBLY	200	0.845 (a) 0.050 (b)	0.845 0.525	169 105
8. RMS TV's & ELBOW TILT & PAN, 34 W; HEATERS (TV's + TILT & PAN), 46 W (ASSUME 50% DUTY CYCLE); LIGHTING, 137 W; FOR 1550 SEC (TASKS 1 THROUGH 7)	1550	0.253	0.230	356.5
TOTAL	1550 (25 MIN, 50 S)	2.168 (c)	1.53 (d)	2374.7

(a) BASIC RMS
(b) RMS HTG
(c) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY
(d) AVERAGE POWER = ENERGY SUMMATION/ACTIVITY TIME SUMMATION

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DATE:	INSTALL BEAM BUILDER ON CONSTRUCTION FIXTURE	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2

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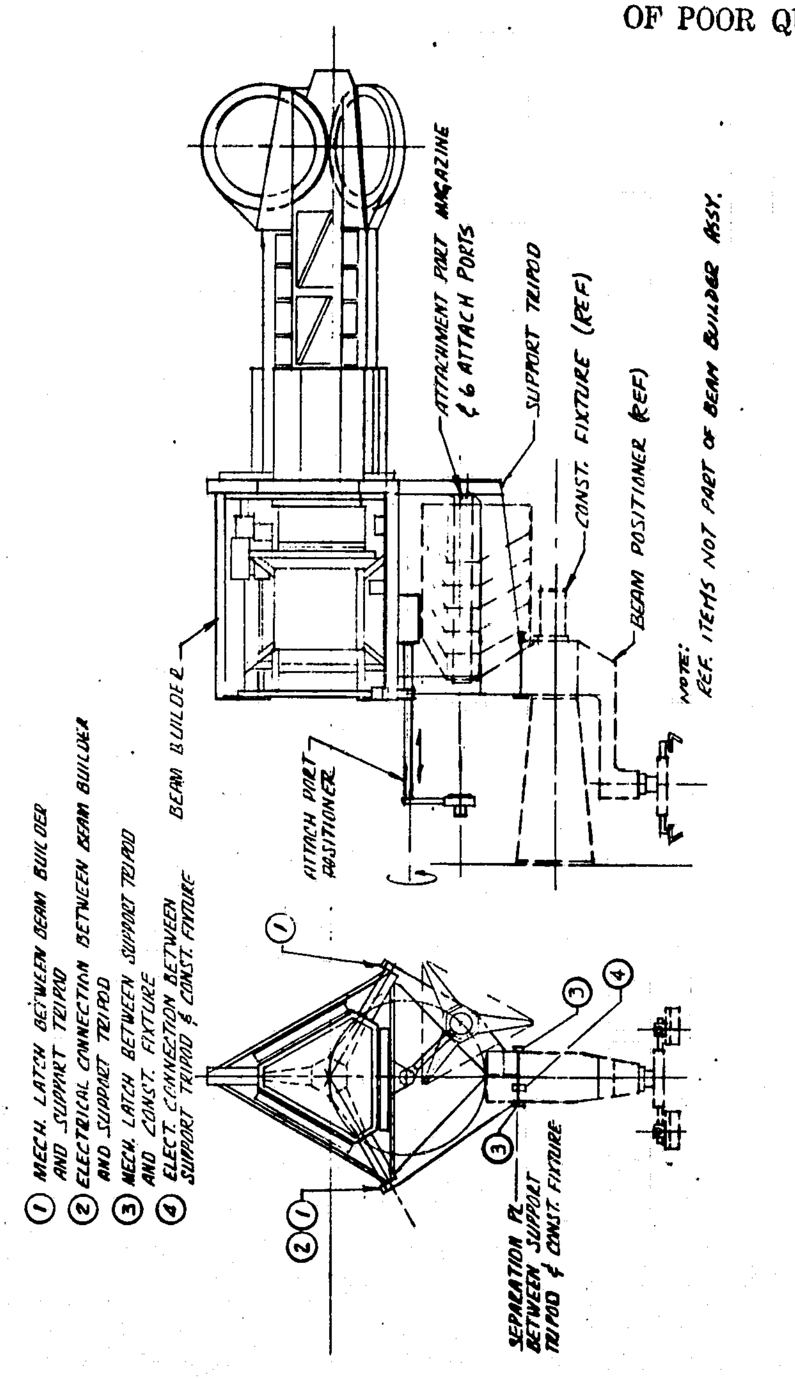

BEAM BUILDER ASSEMBLY

FORM 994-B-1 REV 12-78

ACTIVITY 3.1

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

2.1 Install BB On Fixture → 3.1 Fabricate Base Longitudinal Beam No. 1 → 4.0 Reposition BB on Constr. Fixture

2.1 Install BB On Fixture → 3.2 Install Attach Ports on Longitud. Beam No. 1

REFERENCE DATA

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1. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS)*, Part III, Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine)
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Space Construction Data Base
4. Drawing 42662-72, Attachment Port Details
5. Drawing 42662-50, Tri-Beam Construction Fixture

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DESCRIPTION OF ACTIVITY

Begins with initial heating of cap material and continues until cutoff of beam and separation from beam machine, leaving sufficient cap stub length to permit joining of attachment port on the end. Fabrication methods per Reference 1, with modifications per Reference 4 (pertinent to end stub size). Beam is supported on construction fixture per Reference 5, beam fabrication rates per Reference 5, but first attachment port joining interrupts beam building.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system (Reference 6)
2. Lighting and TV system—Attachment 1
3. Beam-builder machine per Reference 1

TIMELINE: 1.08 m/min. (Reference 5); 1.66 hr for 108 m (see Section 5.3)

POWER/ENERGY (see Section 5.3)

- Beam Builder: 2242 W avg, 3545 W peak, 179.2 kJ/bay, 125 kJ/m, 3.72 kWh/beam
- Lighting: 200 W
- TV: 120 W plus 34 W for heater

CREW LOAD

- IVA: Approximately 0.5 man continuously monitoring
- EVA: 0

TECHNOLOGY DEVELOPMENT REQUIREMENTS: Development of beam builder

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CHECKED BY:		ACTIVITY NO. 3.1
DATE:	FABRICATE BASE LONGITUDINAL BEAM NO. 1	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

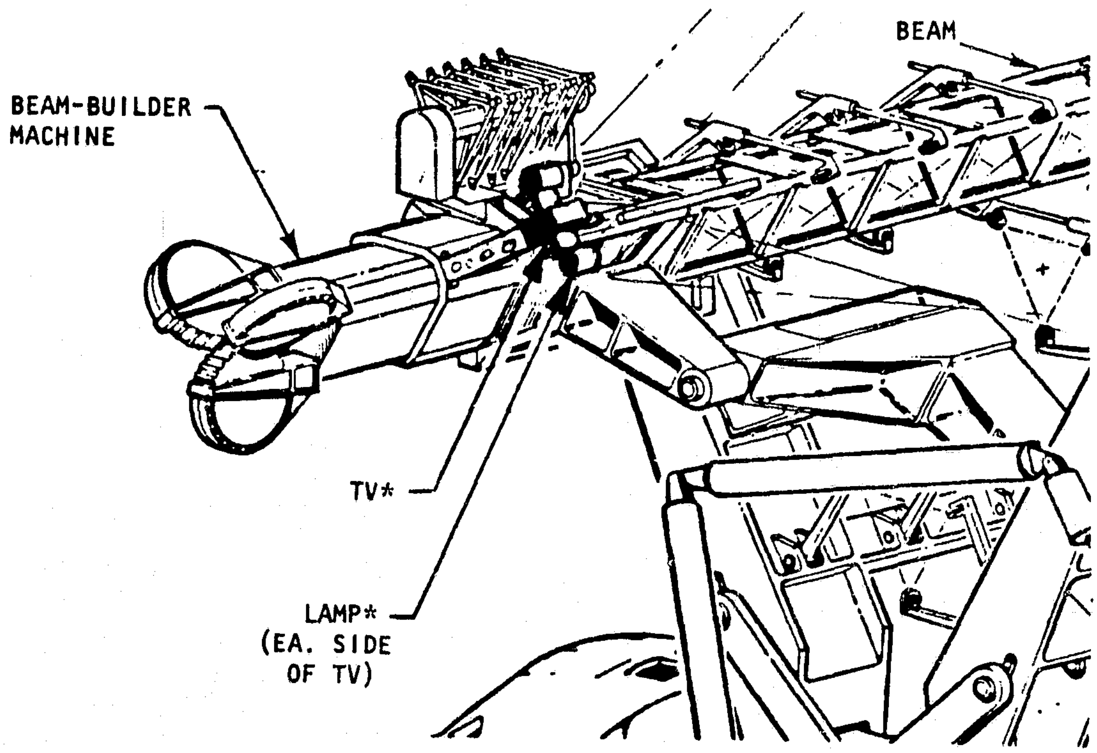
Lighting and TV System Concept Description (see Figure below)

1. Nominal Operations

   - Lamps. Two 100-W incandescent lamps, one mounted on each side of TV camera on beam machine, generally illuminates in same direction as beam is generated, and area where attachment ports are installed.
   - TV. One camera mounted on beam machine, looking outward in same direction as beam is generated. View should permit observing installation of attachment ports and inspection of beam straightness for gross monitoring by crew in cabin. Tilt capability may be required.
   - Hardware can be adapted from RMS system components.

2. Contingency and Special Operations

   - RMS camera and lights can be utilized as required (not included in power/energy data in Data Sheet)



(*Not to scale)

TV and Lamp Location and Orientation

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ACTIVITY 3.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

2.2 Install BB on Fixture → 3.1 Fabricate Base Longitudinal Beam No. 1 → 4.0 Reposition BB on Constr. Fix. —Reposition BB

2.2 Install BB on Fixture → 3.2 Install Attach Ports on Longitudinal Beam No. 1

REFERENCE DATA

1. Drawing 42662-72, Attachment Port Details
2. Drawing 42662-50, Tri-Beam Construction Fixture
3. Space Construction Data Base
4. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS)* Part III, Mid-Term Briefing, CASD-AS78-013, 13 Dec. 1978 (Describes beam-builder machine.)

DESCRIPTION OF ACTIVITY

The activity consists of installing an attachment port at each end of the longitudinal beam. The function begins with rotating an installation device (loaded with attachment port) into alignment with the beam machine. A short section of the beam is fabricated, then the legs of the attachment port are inserted into the beam caps, as shown in Reference 1, and welded in place. The port is released, then the installation device is rotated out of alignment and reloaded with the second attachment port. After the crossbeam is fabricated, cut off, and translated axially away from the beam-builder machine, installation of the second port is performed in a manner similar to that for the first—but in opposite direction of motion. The function is complete when the installation device is rotated out of alignment with the beam.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system and beam-builder machine (Reference 2), including installation device for attachment ports (see Attachment 3).
2. Beam-builder machine, per Reference 4
3. Controls and display systems for operation of installation device for attachment ports
4. TV camera and lights on beam-builder machine (see Attachment 1).

ACTIVITY 3.2

TIMELINE

First Port: 4.12 minutes (interrupts beam fabrication 2.28 minutes)
Second Port (after beam fabrication): 3.86 minutes
Total time for port installation: 7.98 minutes (See Attachment 2)

POWER/ENERGY

Installation Device: Average Power: .146 kW Peak Power: .981 kW
Energy (for two ports): 67.85 kJ (See Attachment 2) Lighting: 200 Watts
TV Camera with Heater, 23W average, 33W peak

CREW LOAD

IVA: One person - continuously during each installation sequence
EVA: 0

TECHNOLOGY DEVELOPMENT REQUIREMENTS

- Development of space-qualified installation device for attachment ports.

- Resistance heating of intermediate filler material for welding of composite materials without active clamping.

ATTACHMENT 1

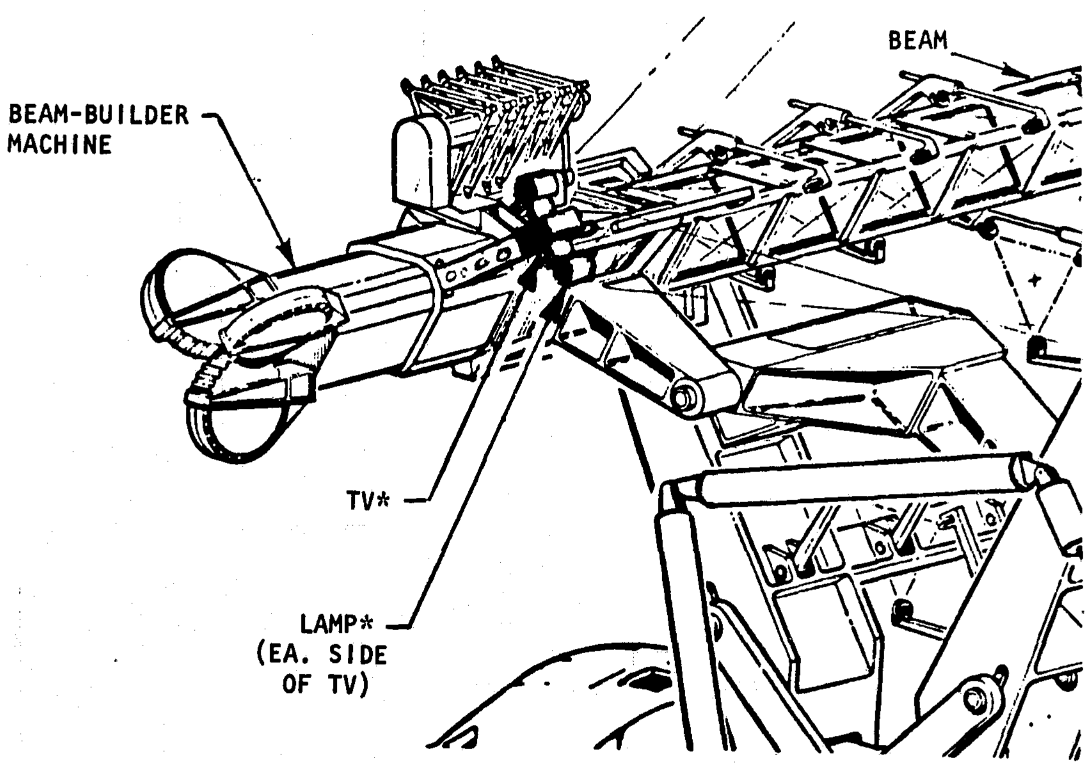
Lighting and TV System Concept Description (see Figure below)

1. Nominal Operations

   - Lamps. Two 100-W incandescent lamps, one mounted on each side of TV camera on beam machine, generally illuminates in same direction as beam is generated, and area where attachment ports are installed.
   - TV. One camera mounted on beam machine, looking outward in same direction as beam is generated. View should permit observing installation of attachment ports and inspection of beam straightness for gross monitoring by crew in cabin. Tilt capability may be required.
   - Hardware can be adapted from RMS system components.

2. Contingency and Special Operations

   - RMS camera and lights can be utilized as required (not included in power/energy data in Data Sheet)



(*Not to scale)

TV and Lamp Location and Orientation

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		DWG. NO.

ATTACHMENT 2

1 Initial installation and checkout of installation device includes running attachment port holder head back to stowed stack of attachment ports mounted on beam machine, grasping one port and axially positioning ready for installation. Subsequently, the attachment port is aligned with the beam; overall concept is shown in Attachment 3.

The loading function for attaching the second port on the beam can be done in parallel with the resumption of fabrication, saving time of installation at the end of beam fabrication. This makes each cycle start with a loaded installation device.

The initial loading operation could be done while the first bay is being fabricated, but this could be an undesirable division of attention of the crew for these initial, critical operations.

2 Electrical resistance welding is performed without any auxiliary clamps, with power supplied through the installation device holder head.

3 Attachment port clip (includes mandrel) can be separately detached from cradle in orbiter payload bay.

ANALYSIS

The tables included herein list tasks, time, power, and energy estimates for each attachment port installation on one longitudinal beam. Thus, summing results of the two time analyses—

Total times: 4.12 (1st port)
3.86 (2nd port)
7.98 minutes (0.133 hr)

Note: Similar results apply to crossbeam fabrication/assembly. The data in the tables will be incorporated into "Space Construction Standards and Practices" for future use.

For the two power/energy analyses—

Total energy: 35.9 (1st port)
33.95 (2nd port)
69.85 kJ

Average energy was derived by dividing total energy by time, e.g.,

$$\frac{33.95 \text{ kJ} \times 1000}{232 \text{ sec}} \text{ (watt-sec)} = 0.146 \text{ kW}$$

In both cases, the peak power estimate was derived from the scaled-up estimate of power for welding crossmembers on the GD beams, per "Space Construction Standards and Practices."

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ACTIVITY 3.2

ATTACHMENT 2 (CONT.)

TIME, POWER, AND ENERGY ESTIMATION FOR ATTACHMENT PORT INSTALLATION DEVICE

TASK DESCRIPTION (FIRST PORT)	DURATION (SEC)	PEAK PWR (kW)	AVG PWR (kW)	ENERGY (kJ)
• ROTATE ATTACHMENT PORT HOLDER 180° INTO ALIGNMENT WITH BEAM BUILDER MACHINE	30		0.075	2.2
• DRIVE ATTACHMENT PORT INTO END OF BEAM	5		0.150	0.75
• WELD (ELECTR. RESISTANCE—ASSUME POWER IS SAME AS FOR BUILDING BEAM)	15	0.981	0.294	23.5
• VERIFY WELD—PULL TEST, 3 TIMES—ONCE PER LEG	15	0.150	0.150	2.25
• RELEASE ATTACH PORT	2		0.010	0.10
• RETRACT INSTALLATION DEVICE AXIALLY	10		0.075	0.75
• ROTATE 180° TO ALIGN WITH DISPENSER FOR ATTACH PORTS (BEAM FABR. MAY RESUME)	30		0.030	0.9
• REPOSITION AXIALLY AND GRASP NEXT ATTACH PORT APPROX. 2 m	30		0.075	2.2
• REPOSITION AXIALLY TO CLEAR ATTACH PORT	15		0.100	1.50
• ROTATE HEAD TO ORIENT PORT FOR SECOND INSTALLATION (180° FROM FIRST PORT)	10		0.075	0.75
• DELAY PERIODS BETWEEN STEPS (VISUAL VERIFICATION/CONTROL OF OPERATIONS) 11 x 5 SEC = 55 SEC	55			
• SHUTDOWN 2 HR UNTIL BEAM FABRICATED (FOR LONGITUDINALS)	20			
TOTALS (FIRST PORT)	247 4.12 MIN.	0.981*	0.145	35.9

*PEAK POWER BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

ATTACHMENT 2 (CONCL.)

TIME, POWER, AND ENERGY ESTIMATION FOR ATTACHMENT PORT INSTALLATION DEVICE

TASK DESCRIPTION (SECOND PORT)	DURATION (SEC)	PEAK PWR (kW)	AVG PWR (kW)	ENERGY (kJ)
• ROTATE ATTACHMENT PORT HOLDER 180° INTO ALIGNMENT WITH BEAM BUILDER MACHINE*	30		0.075	2.2
• DRIVE ATTACHMENT PORT INTO END OF BEAM	5		0.150	0.75
• WELD (ELECTR. RESISTANCE—ASSUME POWER IS SAME AS FOR BUILDING BEAM)	15	0.981	0.294	23.5
• VERIFY WELD—PULL TEST, 3 TIMES—ONCE PER LEG	15	0.150	0.150	2.25
• RELEASE ATTACH PORT	2		0.010	0.10
• RETRACT INSTALLATION DEVICE AXIALLY	10		0.075	0.75
• ROTATE 180° TO ALIGN WITH DISPENSER FOR ATTACH PORTS	30		0.030	0.9
• ROTATE HEAD 180° FOR GRASPING ATTACH PORT	10		0.030	0.3
• REPOSITION AXIALLY & GRASP NEXT ATTACH PORT APPROX. 2 METERS	30		0.075	2.2
• REPOSITION AXIALLY TO PREPARE FOR FIRST PORT INSTALLATION ON FOLLOWING BEAM	10		0.100	1.00
• DELAY PERIODS BETWEEN STEPS (VISUAL VERIFICATION/CONTROL OPERATIONS) 11 × 5 SEC = 55 SEC	55			
• SHUTDOWN/LOCK FOR RELOCATING BEAM BUILDER ON CONSTR. FIXTURE	20			
TOTALS (SECOND PORT)	232 3.86 MIN.	0.981**	0.146	33.95

*PREVIOUSLY LOADED

**PEAK POWER BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY

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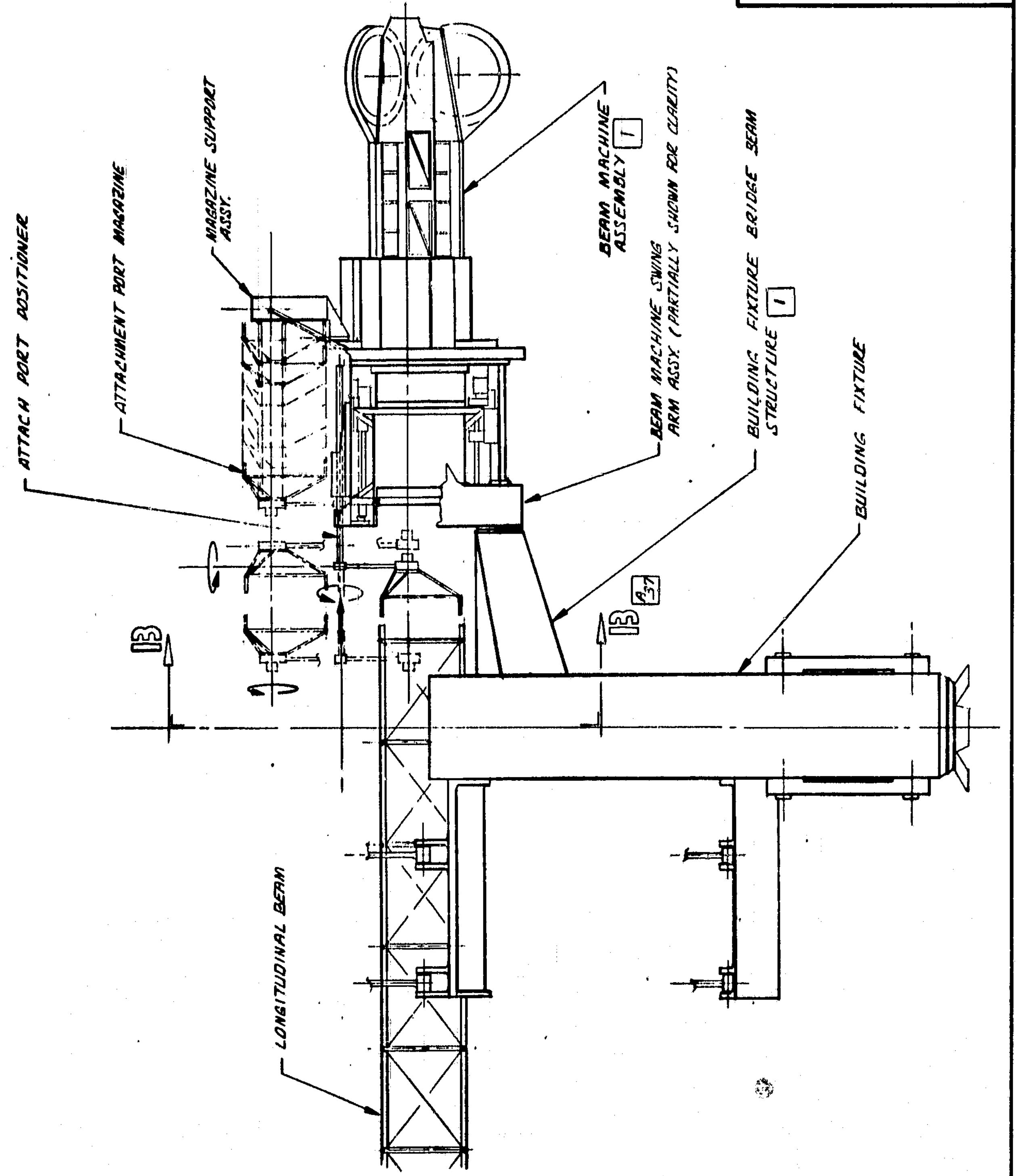
ATTACHMENT 3



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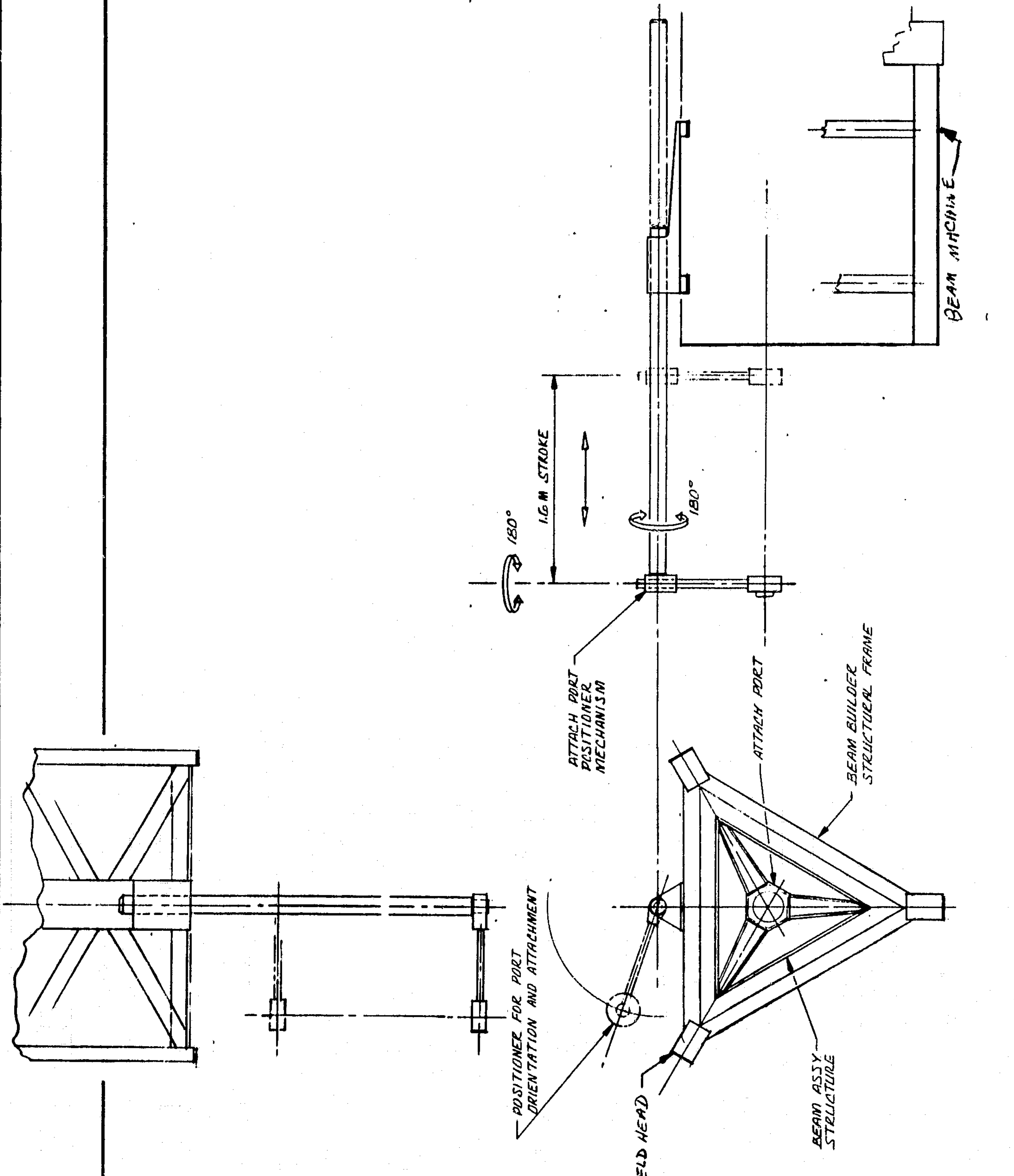


ACTIVITY 4.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

3.1 Fabricate Base Longitudinal Beam No. 1 → **4.0 Reposition Beam Builder on Building Fixture** → 5.1 Withdraw Base Longitudinal Beam No. 1

REFERENCE DATA

1. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS)*, Part III, Mid-Term Briefing, CASD-AS78-013, 13 December 1978.
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Space Construction Data Base
4. Drawing 42662-50, Tri-Beam Construction Fixture

DESCRIPTION OF ACTIVITY: Initial activity to permit relocation of the beam builder is to activate the release mechanism of the locking device which provides structural attachment and alignment of the beam builder to the construction fixture. After the release function is performed, the beam builder's power drive unit, located in the crossbeam support of the building fixture, is actuated, driving the swing arm supporting the beam builder from position No. 1, 120 degrees counterclockwise to beam position No. 2. Activation of the positioning and locking mechanism will secure the beam builder in its proper orientation so fabrication of longitudinal beam No. 2 can be initiated. (See Attachment 2.)

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture (Reference 4)
2. Beam builder machine (Reference 1)
3. Lighting and TV system (Attachment 1)

TIMELINE: 7 minutes (see Attachment 2)

POWER/ENERGY

Peak power, 2.7 kW; average power 2.5 kW; energy, 0.29 kWh (see Attachment 2)

CREW LOAD

IVA: Approximately 0.5 man for monitoring operation
EVA: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Developing techniques for platform assembly

ATTACHMENT 1

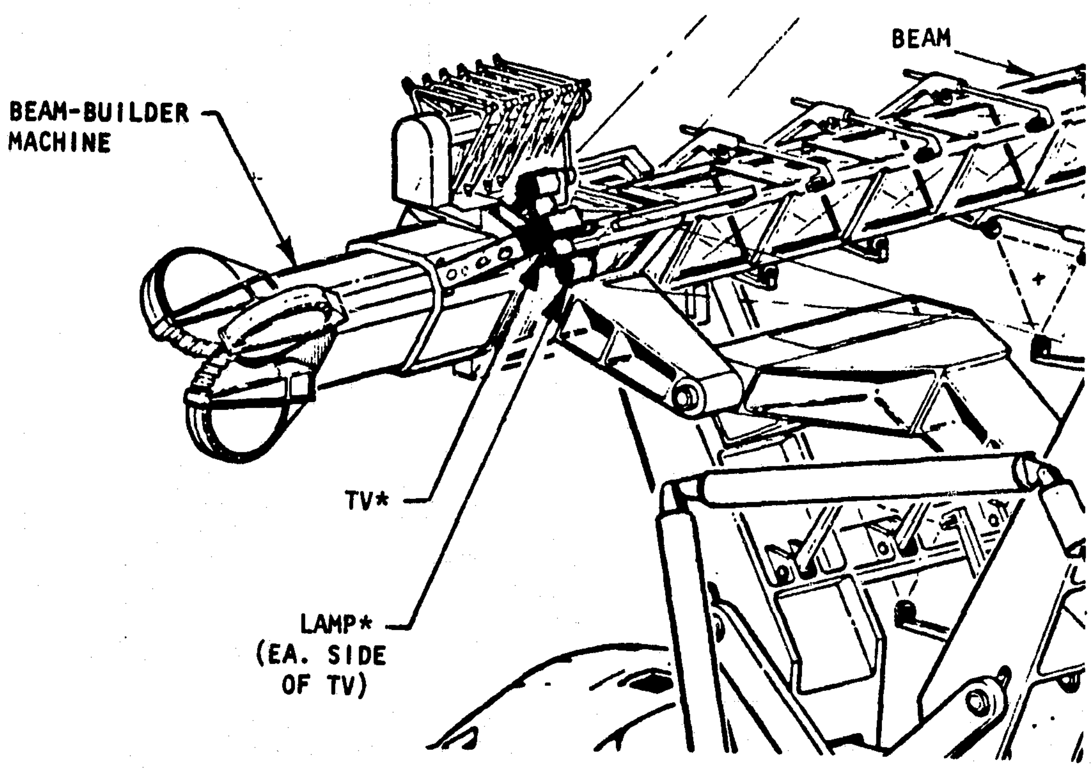
Lighting and TV System Concept Description (see Figure below)

1. Nominal Operations

   - Lamps. Two 100-W incandescent lamps, one mounted on each side of TV camera on beam machine, generally illuminates in same direction as beam is generated, and area where attachment ports are installed.
   - TV. One camera mounted on beam machine, looking outward in same direction as beam is generated. View should permit observing installation of attachment ports and inspection of beam straightness for gross monitoring by crew in cabin. Tilt capability may be required.
   - Hardware can be adapted from RMS system components.

2. Contingency and Special Operations

   - RMS camera and lights can be utilized as required (not included in power/energy data in Data Sheet)



(*Not to scale)

TV and Lamp Location and Orientation

ACTIVITY 4.0

ATTACHMENT 2

TIME, POWER, AND ENERGY ANALYSIS FOR REPOSITIONING THE BEAM BUILDER WHILE SUPPORTED ON THE BUILDING FIXTURE

Assumptions

For the effort of repositioning the beam builder, certain assumptions have to be considered as a normal condition for this operation. The first is that all electrical and data leads will remain connected during any rotation cycle. The rotation drive mechanism for the swing arm support will be located inside the structure portion of the fixture crossbeam. Orientation and position verification, plus locking features, would also be built into the beam builder support and fixture crossbeam structure.

Analysis

The following table lists tasks, time, power, and energy estimates for the beam builder and fixture configuration.

Task Description	Duration (sec)	Power (kW)		Energy (kJ)
		Peak	Average	
Preparation	120	-	-	-
Disconnect locking device	5	0.005	0.005	Negl.
Rotate beam builder	120	0.200	0.200	2.4
Reconnect locking device	5			Negl.
Position port attach fitting	30	0.075	0.075	2.2
Checkout (B.B. average power)	140			
• Lighting		0.200	0.200	0.84
• TV camera and heater	(420)*	0.033	0.023	0.10
• Beam builder standby		2.24	2.24	940.8
Summary	420	2.673†	2.526††	1061 (0.295 kWh)

*Non-additive time

†Peak power summary based upon peak power of individual activities, subjectively estimated, being performed simultaneously.

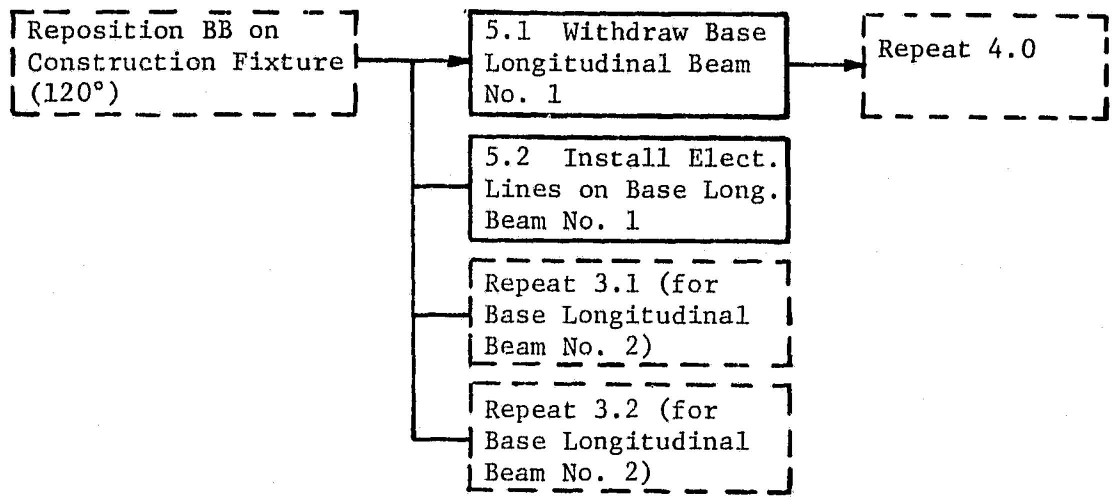
$$\dagger\dagger\text{Average power} = \frac{\text{energy summation}}{\text{activity time summation}}$$

ACTIVITY: 5.1 & 5.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Dwg. 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Dwg. 42662-50, Tri-Beam Construction Fixture

DESCRIPTION OF ACTIVITY

Power and communications line bundles are packaged on a single reel with the Velcro attachment strips in place, as shown in Attachment 3. The bundles are first attached to the longitudinal beam near the aft end and then "laid on" as the beam is withdrawn under the reel. The Velcro attachment strips are automatically attached to the beam crossmembers as the beam is withdrawn (Attachment 3). The final attachment is at a crossmember near the control center module end, after which the reel is removed.

CONSTRUCTION SUPPORT EQUIPMENT: (1) RMS with appropriate end effector, (2) wire bundle dispensing reel, (3) wire bundle attachment mechanism—see Attachment 3, (4) lighting and TV, and (5) tri-beam construction fixture.

TIMELINE: See Attachments 1 and 2; 8280 seconds (2 hr, 18 min.)

POWER/ENERGY: Beam withdrawal and wire attachment—peak power, 0.1 kW; average power, 0.05 kW; energy, 3840 kJ. Lighting—200 W. TV camera with heater—23 W average, 33 W peak.

CREW LOAD: IVA—One man continously, monitoring; EVA—none

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Wire bundle dispensing and attachment system.

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ATTACHMENT 1

BASIS FOR TIMELINE

(1) Beam withdrawal rate assumed to be 2.16 meters/minute, which is the same as the rate of beam advance.

(2) Wire bundle attachment to be automatic; time estimated to be 40 seconds, maximum, per crossmember.

PREPARED BY: C. Fritz	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES 5.1 & 5.2
DATE: 11/20/79	5.1 Withdraw Base Longitudinal Beam No. 1 5.2 Install Elec. Lines on Base Long. Beam No. 1	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

Timeline Summary

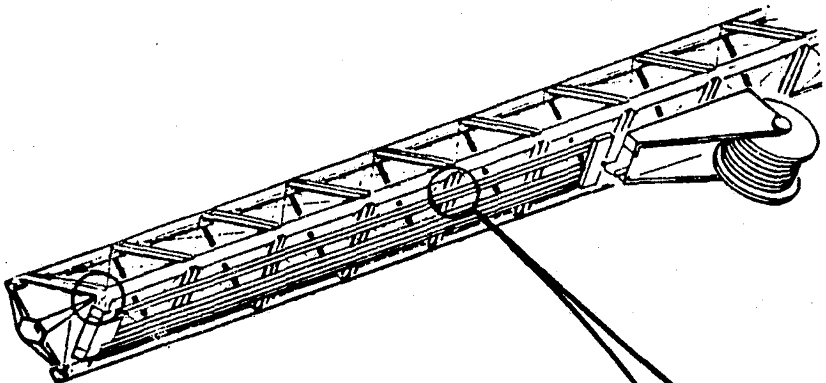
	Operation	Time
1.	Activate reel and attachment mech.	5 min.
2.	Initial attachment	40 sec
3.	Withdraw beam 1.434 meters	40 sec
4.	Attach wire bundle to beam	40 sec
5.-194.	Repeat Steps 3 and 4 95 times each	126 min.
195.	Deactivate reel	5 min.
	Total	138 min. (2 hr, 18 min.)

FORM 994-B-1 REV 12-78

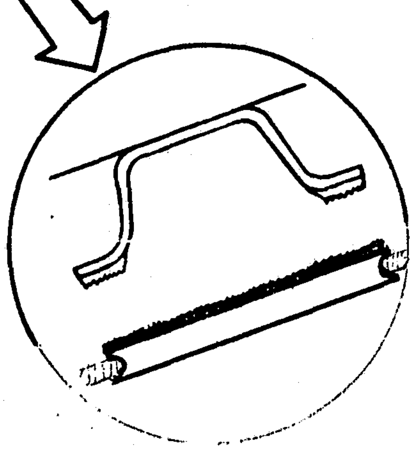
PREPARED BY: C. Fritz	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES 5.1 & 5.2
DATE: 11/20/79	5.1 Withdraw Base Longitudinal Beam No. 1 5.2 Install Elec. Lines on Base Long. Beam No. 1	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3

WIRE INSTALLATION—LONGITUDINAL BEAM



- DURING WITHDRAW TRANSLATION WORK STATION NO. 1
- INTEGRAL CABLE RUN
  - SINGLE REEL
  - FLEX RAILROAD TRACK CONCEPT
  - INTEG. CROSSBEAM CONNECTORS
- "LINEAR" REEL DRIVE
- AUTOMATED VELCRO ATTACHMENT



VELCRO ATTACHMENT

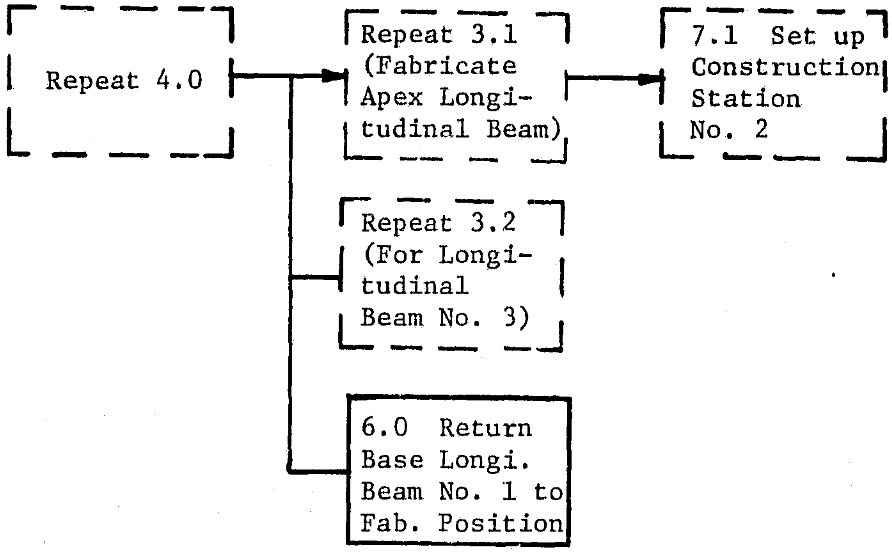
FORM 994-B-1 REV 12-78

ACTIVITY 6.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-50, Tri-Beam Construction Fixture

DESCRIPTION OF ACTIVITY

When the laying of the wire bundles has been completed (Activity 5.2), Beam No. 1 is translated through the construction fixture rollers back to the position which it occupied at the completion of fabrication.

CONSTRUCTION SUPPORT EQUIPMENT

Tri-beam construction fixture—rollers, roller drive mechanism, and control system. (See Attachment 1.)

TIMELINE 2.16 meters/minute, 50 minutes for 108 meters (see Section 5.3)

POWER/ENERGY Construction fixture—peak power = 0.10 kW, average power = 0.10 kW, energy = 381 kJ. Lights—200 W. TV with heater—23 W average, 33 W peak. Total energy—0.356 kJ. (see Section 5.3)

CREW LOAD IVA—approximately 0.5 man continuously monitoring; EVA—none

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Development of construction fixture roller drive and control system.

J. Roebuck PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		Activity No. 6.0
DATE: 11/28/79	Return Base Longitudinal Beam No. 1 to Fabrication Position	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

The rollers and roller drive mechanisms must accommodate the specific mass of just one longitudinal beam plus attached electrical wiring (approximately 4177 lb = 1894 kg), as well as the lower mass of beam alone (at start of previous activity (5.1), and mass of completed platform with payloads.

A constant speed drive control is required once the beam has been accelerated. A braking method also must be incorporated to stop motion. A position sensing system is needed to assure correct stopping location. Adequate redundancy in sensing may include a physical power shutoff trigger device and a revolution counter or timer to alert crew for monitoring the stopping period.

The translation speed selected for this activity is very conservative, being that used by the beam builder (during its motion periods). A further analysis may indicate much faster translation rates would be desirable to minimize overall time and energy requirements. A free-wheeling roller system might also be employed, since only friction of the rollers will require power, once motion is initiated. This approach would permit variable (non-controlled) translation rates.

At this time there is no apparent schedule impact due to the selected translation rate, since beam fabrication (which is proceeding simultaneously) is probably the pacing activity.

FORM 994-B-1 REV 12-78

J. Roebuck PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY NO. 6.0
DATE: 11/28/79	Return Base Longitudinal Beam No. 1 to Fabrication Position	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

6.0 POWER/ENERGY ANALYSIS

Two methods were investigated as means to estimate power requirements for the translation of the beam.

Method 1

This method is based upon fundamental physics analysis of accelerating the mass to the stated velocity, then assuming a constant power draw at the same rate until the beam is stopped. Efficiency factors of 25% and 2.5% were assumed.

Method 2

This method is based on an overall power demand proportional to weight and velocity, derived from empirical considerations. The results were higher and judged more conservative and acceptable for the application in this activity.

SUMMARY

The power requirements for actual beam translation are trivial compared to other demands, even those for lighting and TV to monitor the motion.

FORM 994-B-1 REV 12-78

ACTIVITY 7.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

Repeat 3.1 (Fabricate Apex Longitudinal Beam) → 7.0 Set Up Construction Station No. 2 → 8.1 Relocate BB for Cross/Transverse Beam Fabrication; 8.2 Reconfigure Construction Fixture

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-52, No. 2 Construction Station—General Arrangement
3. Drawing 42662-66, Orbiter Bay Stowage, First Launch

DESCRIPTION OF ACTIVITY

Remove elements of the No. 2 station from the orbiter bay and set up astride the longerons. (See Attachments 1 and 2 for details.)

CONSTRUCTION SUPPORT EQUIPMENT

1. RMS with rotational joint between shoulder and elbow and special end effector
2. Lighting and TV system

TIMELINE 52.67 minutes (see Attachment 1)

POWER/ENERGY

Peak power, 2.199 kW; average power, 1.767 kW; energy, 5800 kJ (See Attachment 1)

CREW LOAD

IVA astronaut—52.67 minutes, continuous

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Remote control, self-aligning, electrical connector

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ACTIVITY 7.0

ATTACHMENT 1

Time, Power, and Energy Estimates for setting up No. 2 Construction Station

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVERAGE PWR. (kW)	ENERGY (kJ)
1. OPEN THE PAYLOAD RETENTION LATCHES WHICH SECURE THE Y-FRAME, WITH ITS STACKS OF END PORT FITTINGS, IN THE ORBITER BAY.	30	0.02	0.02	0.6
2. USE THE RMS TO REMOVE THE Y-FRAME FROM THE ORBITER BAY, ROTATE IT 90°, AND SEAT THE MOUNTING TRUNNIONS IN THE PAYLOAD RETENTION LATCHES.	1380	0.845[1] (BASIC RMS) 1.050[2] (RMS HEATER)	0.845 0.525 (50% DUTY)	1166.1 724.5
3. CLOSE THE LATCHES, RELEASE THE RMS, AND MOVE RMS TO TEMPORARY HOLD POSITION.	50 (LATCHES) 60 (RMS)	0.03 1.895	0.03 1.37	1.5 82.2
4. ACTUATE THE REMOTE ELECTRICAL CONNECTION BETWEEN THE Y-FRAME AND THE ORBITER BAY.	30	0.01	0.01	0.3
5. OPEN THE PAYLOAD RETENTION LATCHES WHICH SECURE THE REEL ASSEMBLY IN ORBITER BAY. REEL ASSEMBLY CONSISTS OF: • ELECTRICAL CABLE REEL (FOLDED) • INTERSECTION FITTING APPLICATOR • DRIVE ROLLERS • STRUCTURAL FRAME ASSEMBLY	30	0.02	0.02	0.6
6. USE THE RMS TO REMOVE THE REEL ASSEMBLY FROM THE ORBITER BAY, ROTATE IT, AND SET IT IN ITS DEPLOYED LOCATION ON THE RH LONGERON AND Y-FRAME, AND IN THE RETENTION LATCHES.	1380	1.895	1.37	1890.6
7. CLOSE THE LATCHES AND REMOVE THE RMS TO TEMPORARY HOLD POSITION	50 (LATCH) 60 (RMS)	0.02 1.895	0.02 1.37	1.0 82.2

ACTIVITY 7.0

ATTACHMENT 1 (Cont.)

Time, Power, and Energy Estimates for setting up No. 2 Construction Station

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVERAGE PWR. (kW)	ENERGY (kJ)
8. ACTUATE THE REMOTE ELECTRICAL CONNECTION BETWEEN THE Y-FRAME AND THE REEL ASSEMBLY FRAME.	30	0.01	0.01	0.3
9. UNFOLD THE ELECTRICAL CABLE REEL FROM ITS STOWED POSITION AND ROTATE IT TO ITS DEPLOYED LOCATION AND LATCH IT IN PLACE.	60	0.03	0.03	1.8
10. TV AND LIGHTING REQUIRED THROUGHOUT THE SETTING UP OF NO. 2 STATION.	(3160, TIME NOT ADDITIVE)	0.585 (3)	0.565	1848.6
TOTALS AND AVERAGES	3160	2.199 (5) (1)+(2)+(3)	1.767 (6)	5800.3

NOTES

(1) THE RMS IS DIRECTED FROM THE ORBITER CABIN AND NOT IN A CHERRY PICKER MODE.

(2) THE FOLLOWING ACTIVITY STEPS ARE INITIATED FROM THE ORBITER CABIN BY ELECTRICAL SWITCHES—STEPS 1, 3, 4, 5, 7, 8, 9.

(3) TV WITH HEATERS: 46 W AVERAGE, 66 W PEAK (2 TV CAMERAS)

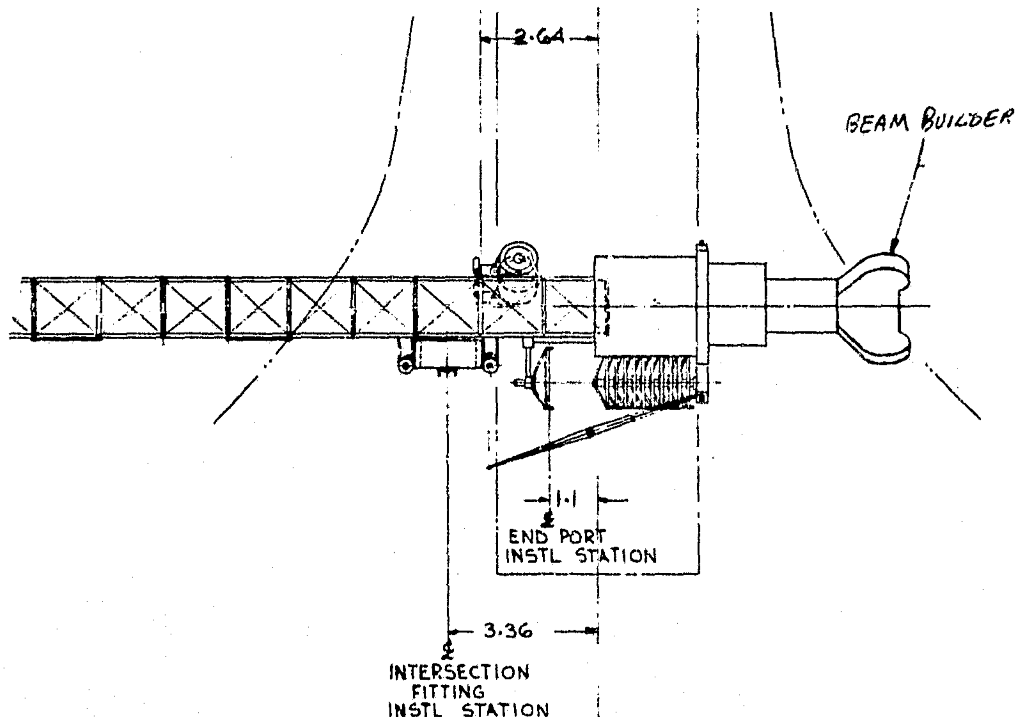
(4) LIGHTING, 519 W (3 LAMPS).

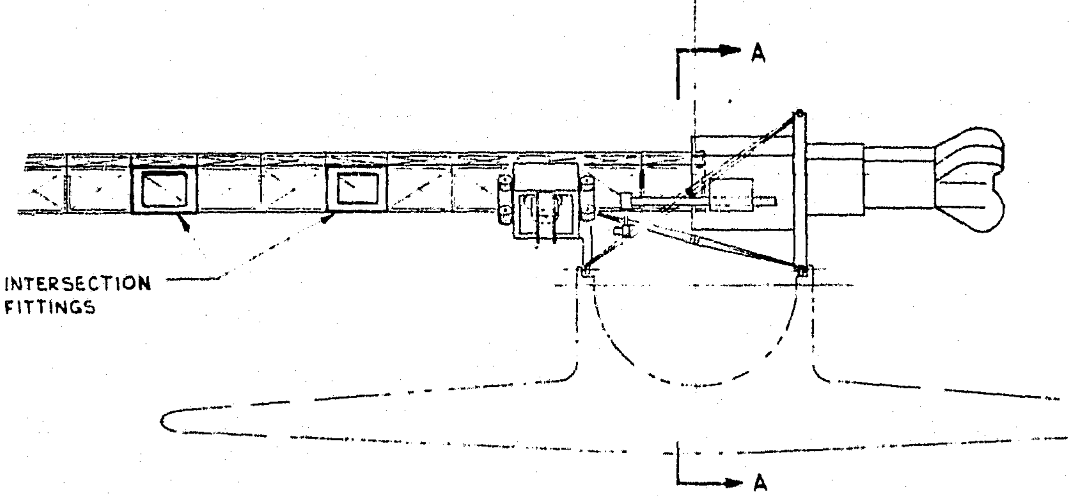
(5) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(6) AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 7.0
DATE:	SET UP CONSTRUCTION STATION NO. 2	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2





FOR CLARITY, THE STORED END PORTS ARE OMITTED FROM THIS VIEW.

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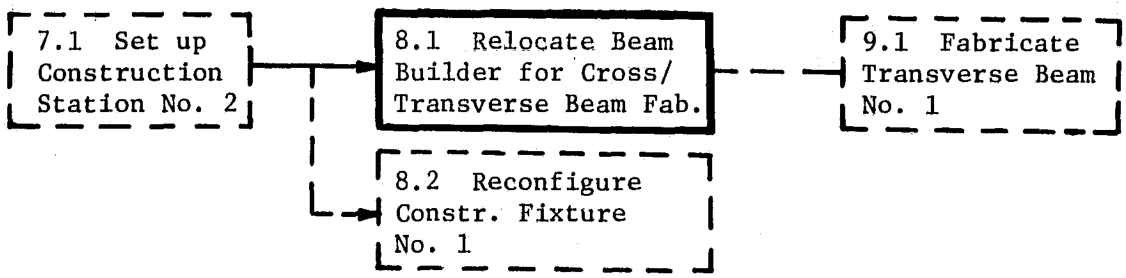
ACTIVITY 8.1

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-50, Construction Fixture No. 1
3. Drawing 42662-52, Construction Station No. 2

DESCRIPTION OF ACTIVITY (see Attachments 1, 2, and 3)

The activity consists of releasing the beam builder from the support tripod and using the RMS to transport and install the beam builder onto the Y-frame of Construction Station No. 2. The support tripod is removed from Construction Fixture No. 1, using the RMS, and stowed in the orbiter bay.

CONSTRUCTION SUPPORT EQUIPMENT

RMS, lighting, and TV

TIMELINE

3070 seconds (51 minutes, 10 seconds) (see Attachment 1)

POWER ENERGY

Average power, 2.156 kW; peak power, 2.259 kW; energy, 6619.5 kJ (see Attachment 1)

CREW LOAD

IVA, one man continuous; EVA, none

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None.

ACTIVITY 8.1

ATTACHMENT 1

Time, Power, and Energy Estimation for Relocation of Beam Builder onto Construction Station No. 2

TASK DESCRIPTION	DURATION (sec)	PEAK POWER (kW)	AVERAGE PWR (kW)	ENERGY (kJ)
1. GRASP THE BEAM BUILDER (ON THE SUPPORT TRIPOD AT CONSTRUCTION FIXTURE NO. 1) WITH THE RMS.	60	0.845* 1.050**	0.845 1.050	50.7 63.0
2. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN, RELEASE THE MECHANICAL AND ELECTRICAL CONNECTIONS BETWEEN THE BEAM BUILDER AND THE SUPPORT TRIPOD.	30	0.02	0.02	6
3. USING THE RMS, TRANSPORT THE BEAM BUILDER TO THE VICINITY OF CONSTRUCTION STATION NO. 2.	600	0.845* 1.050**	0.845 1.050	507 630
4. USING THE RMS, PLACE THE BEAM BUILDER IN POSITION ON CONSTRUCTION STATION NO. 2	600	0.845* 1.050**	0.845 1.050	507 630
5. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN, SECURE THE MECHANICAL LATCHES TO RETAIN THE BEAM BUILDER TO CONSTRUCTION STATION NO. 2	30	0.02	0.02	6
6. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN, MATE THE ELECTRIC INTERFACE CONNECTOR BETWEEN THE BEAM BUILDER AND CONSTRUCTION STATION NO. 2	30	0.02	0.02	6
7. RELEASE THE RMS FROM THE BEAM BUILDER AND MOVE AWAY FROM CONSTRUCTION STATION NO. 2 TOWARD CONSTRUCTION FIXTURE NO. 1	200	0.845* 1.050**	0.845 1.050	169 210
8. GRASP THE SUPPORT TRIPOD (ON CONSTRUCTION FIXTURE NO. 1) WITH THE RMS	60	0.845* 1.050**	0.845 1.050	50.7 63.0
9. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN, RELEASE THE MECHANICAL AND ELECTRICAL CONNECTIONS BETWEEN THE SUPPORT TRIPOD AND CONSTRUCTION FIXTURE NO. 1	30	0.02	0.02	6

*BASIC RMS
**RMS HEATING

ACTIVITY 8.1

ATTACHMENT 1 (Cont.)

Time, Power, and Energy Estimation for Relocation of Beam Builder onto Construction Station No. 2

TASK DESCRIPTION	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
10. USING THE RMS, TRANSPORT THE SUPPORT TRIPOD TO THE ORBITER BAY.	600	0.845* 1.050**	0.845 1.050	507 630
11. USING THE RMS, PLACE THE SUPPORT TRIPOD IN ITS PAYLOAD RETENTION LATCHES IN THE ORBITER BAY.	600	0.845* 1.050**	0.845 1.050	507 630
12. BY REMOTE CONTROL FROM THE ORBITER BAY, SECURE THE PAYLOAD RETENTION LATCHES FOR THE SUPPORT TRIPOD.	30	0.02	0.02	6
13. RELEASE THE RMS AND MOVE IT AWAY FROM THE SUPPORT TRIPOD.	200	0.845* 1.050**	0.845 1.050	169 210
14. RMS TV WITH HEATER—23 W AVERAGE, 33 W PEAK; LIGHTING, 200 W—FOR 2870 SECONDS (TASKS 1 THROUGH 13).	3070	0.233	0.223	684.6
TOTAL	3070 50 MIN., 10 SEC	2.259†	2.023	6212

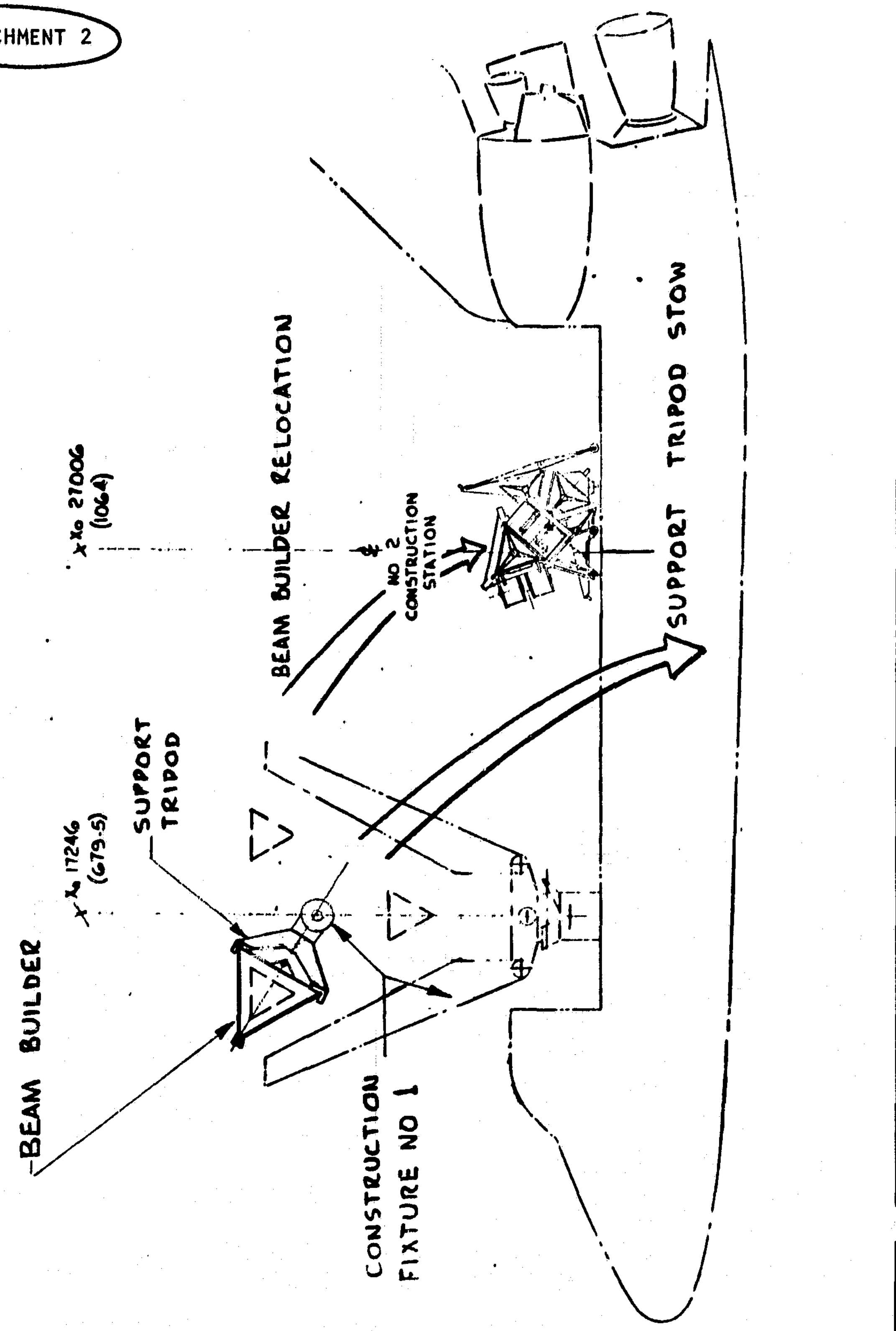
*BASIC RMS

**RMS HEATING

†PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

PREPARED BY: R. HART	Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 8.1
DATE: 27 NOV 1979	RELOCATE BEAM BUILDER FOR CROSS/TRANSVERSE BEAM FABRICATION	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



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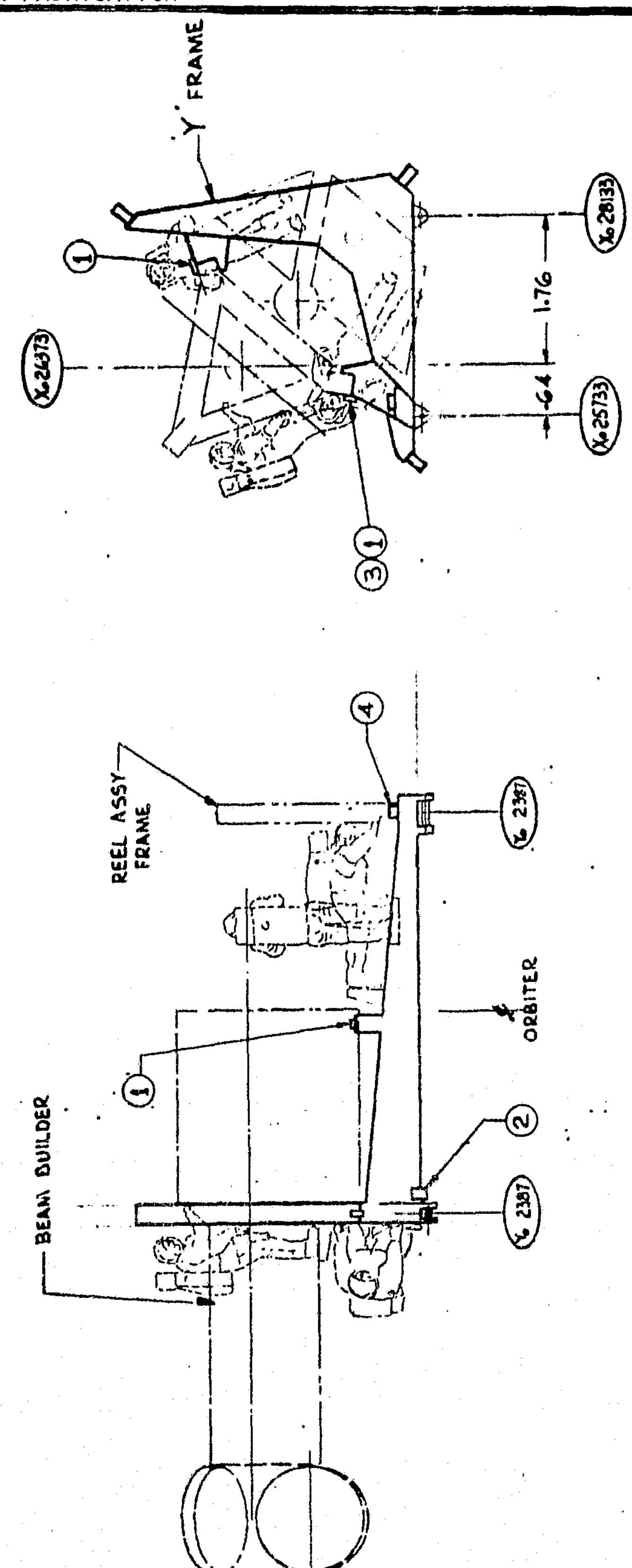
PREPARED BY: R. HART	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 8.1
DATE: 27 NOV 1979	RELOCATE BEAM BUILDER FOR CROSS/TRANSVERSE BEAM FABRICATION	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3

BEAM BUILDER INSTALLED AT CONSTRUCTION STATION NO. 2

1. MECHANICAL LATCHES
2. ELECTRICAL INTERFACE BETWEEN BEAM BUILDER AND NO. 2 STATION



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ACTIVITY 8.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT   ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

7.1 Set Up Construction Station No. 2 → 8.1 Relocate BB for Cross/Transverse Beam Fabrication → 9.1 Fabricate Transverse Beam (No. 1)

7.1 Set Up Construction Station No. 2 → 8.2 Reconfigure Construction Fixture and occupy EVA Work Station

REFERENCE DATA

1. Space Construction Data Base
2. Dwg. 42662-50, Construction Fixture No. 1
3. Dwg. 42662-55, EVA Work Station

DESCRIPTION OF ACTIVITY

The activity begins when the EVA astronaut with MMU arrives at the docking station at Construction Fixture No. 1, as shown on Attachment 2. The astronaut docks the MMU to the construction fixture and remotely controls the cherry picker to his vicinity. He transfers to the cherry picker and maneuvers to his work position to join Transverse Beam No. 1. Parallel in time to these EVA operations, the construction fixture is reconfigured by remote control from the orbiter crew cabin. The reconfiguration consists of repositioning the cross-brace cable reels and the beam positioner.

CONSTRUCTION SUPPORT EQUIPMENT

MMU, TV, lights

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TIMELINE

780 seconds (13 minutes) (see Attachment 1)

POWER/ENERGY

Peak power, 0.433 kW; average power, 0.258 kW; energy, 201 kJ (see Attachment 1)

CREW LOAD

EVA: One man, continuous
IVA: One man, part time

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ACTIVITY 8.2

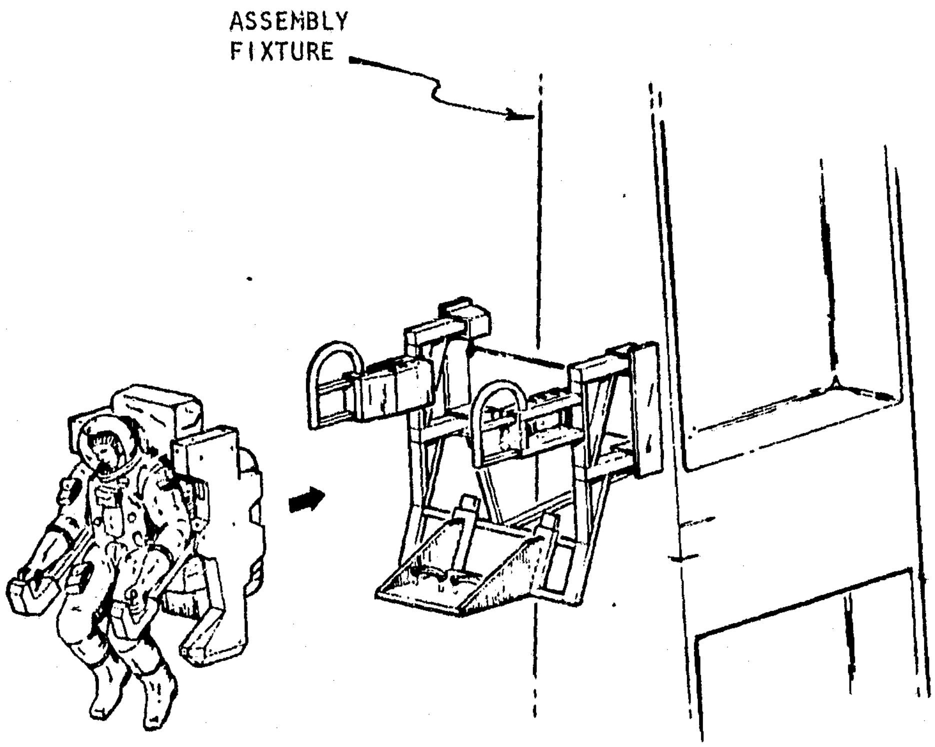
ATTACHMENT 1

Time, Power, and Energy Estimation for EVA Astronaut Arrives at Construction Fixture No. 1 and Reconfiguration of Construction Fixture No. 1

TASK DESCRIPTION		DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. EVA ASTRONAUT IN MMU ARRIVES AT THE DOCKING STATION ON CONSTRUCTION FIXTURE NO. 1, MANUALLY UNFOLDS THE TWO ARM RESTRAINTS AND THE FOOT RESTRAINTS WHICH ARE PART OF THE DOCKING STATION.		180	-	-	-
2. EVA ASTRONAUT IN MMU MANEUVERS TO BACK INTO THE DOCKING STATION AND SECURE HIMSELF		120	-	-	-
3. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN, THE CHERRY PICKER IS MANEUVERED TO BE WITHIN REACH OF THE EVA ASTRONAUT.		180	0.10	0.10	18
4. THE EVA ASTRONAUT TRANSFERS FROM THE DOCKING STATION TO THE CHERRY PICKER, LEAVING THE MMU SECURED IN THE DOCKING STATION.		120	-	-	-
5. THE EVA ASTRONAUT IN THE CHERRY PICKER MANEUVERS TO HIS WORK STATION TO JOIN TRANSVERSE BEAM NO. 1		180	-	-	-
6. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN: • DEPLOY THE 6 CROSS-BRACE CABLE REELS & LOCK • DEPLOY THE BEAM POSITIONER (PARALLEL IN TIME TO TASK 1)		 (120) (60)	 0.05 0.05	 0.05 0.05	 6 3
7. LIGHTS, 200 W (20 W AT DOCKING STATION, 180 W AT CHERRY PICKER)		780	0.20	0.20	156
8. TV WITH HEATER: 23 W AVERAGE, 33 W PEAK		240	0.33	0.23	18
*PEAK POWER SUMMARY BASED ON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.	TOTAL	780 (13 MIN.)	0.433*	0.258	201

PREPARED BY: R. HART	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 2
CHECKED BY:		ACTIVITY 8.2
DATE: 26 NOV 1979	EVA ASTRONAUT ARRIVES AT CONSTRUCTION FIXTURE NO. 1	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



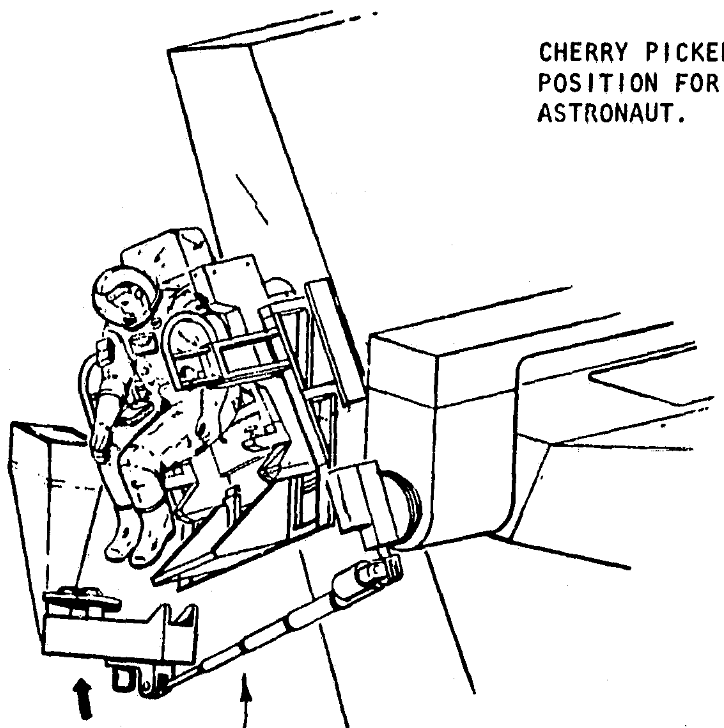
ASTRONAUT WITH MMU BACKS INTO THE DOCKING STATION

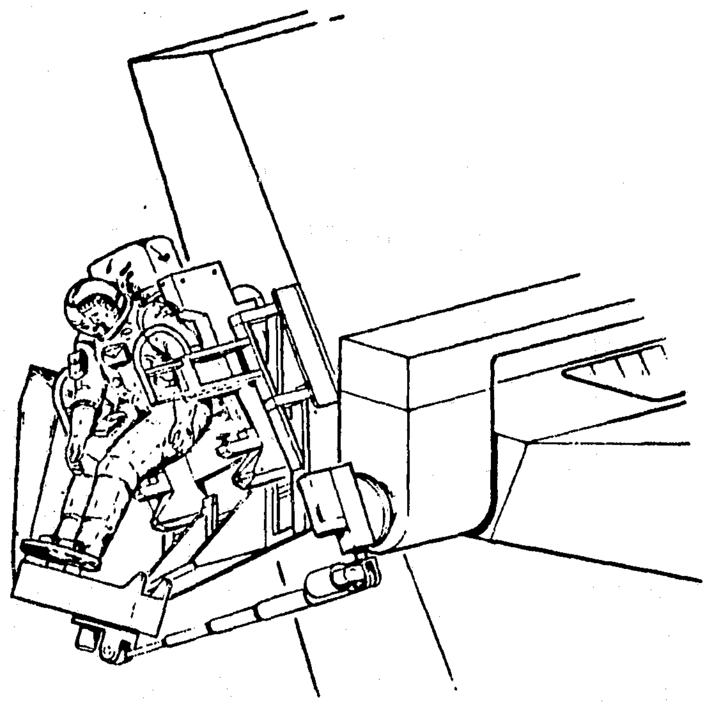
FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 2 OF 2
CHECKED BY:		ACTIVITY 8.2
DATE:	EVA ASTRONAUT ARRIVES AT CONSTRUCTION FIXTURE NO. 1	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2 (Cont.)

CHERRY PICKER IS MOVED INTO POSITION FOR BOARDING BY ASTRONAUT.





FORM 994-B-1 REV 12-78

Satellite Systems Division
Space Systems Group
Rockwell International

ACTIVITY 9.1

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM

ACTIVITY

8.1 Relocate BB for Cross/Transverse Beam Fabrication

8.2 Reconfigure Construction Fixture

9.1 Fabricate Transv. Beam (No. 1)

9.2 Join Intersection Fittings to Transv. Beam (No. 1)

10.0 Transport Transverse Beam (No. 1) & Position for Joining

REFERENCE DATA

1. Convair Division of General Dynamics, Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), Part III Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine)
2. Drawing No. 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Space Construction Data Base
4. Drawing No. 42662-52, Number 2 Construction Station

DESCRIPTION OF ACTIVITY

Begins with initial heating of cap material and continues until cutoff of beam and separation from beam machine a sufficient distance to permit joining of intersection fitting on end (per Reference 2). Fabrication methods per Reference 1, with modifications per Attachment 1 (pertinent to end stub length). Beam is supported at work station no. 2 construction fixture per Reference 4 (see Attachment 2). Beam fabrication rates per Reference 1, but first joining of intersection fitting interrupts beam building. (Typical for all transverse beams)

CONSTRUCTION SUPPORT EQUIPMENT

1. Work Station No. 2 Construction Fixture System (Reference 4)
2. Lighting & TV System (see Construction Activity Data Sheet 3.1)
3. Beam-Builder Machine per Reference 1

TIMELINE 1.08 meters/minute (Reference 5); 5.31 min for 5.736 meters

POWER/ENERGY Beam Builder: 2.242 kW avg, 3.546 kW peak, 179.2 kJ/Bay, 125 kJ/M, .20 KWH/Beam. Lighting: 200 W. TV with heater 23 W avg, 33 W peak

CREW LOAD IVA: Approx. 0.5 man continuously monitoring EVA: 0

TECHNOLOGY DEVELOPMENT REQUIREMENTS Development of beam builder

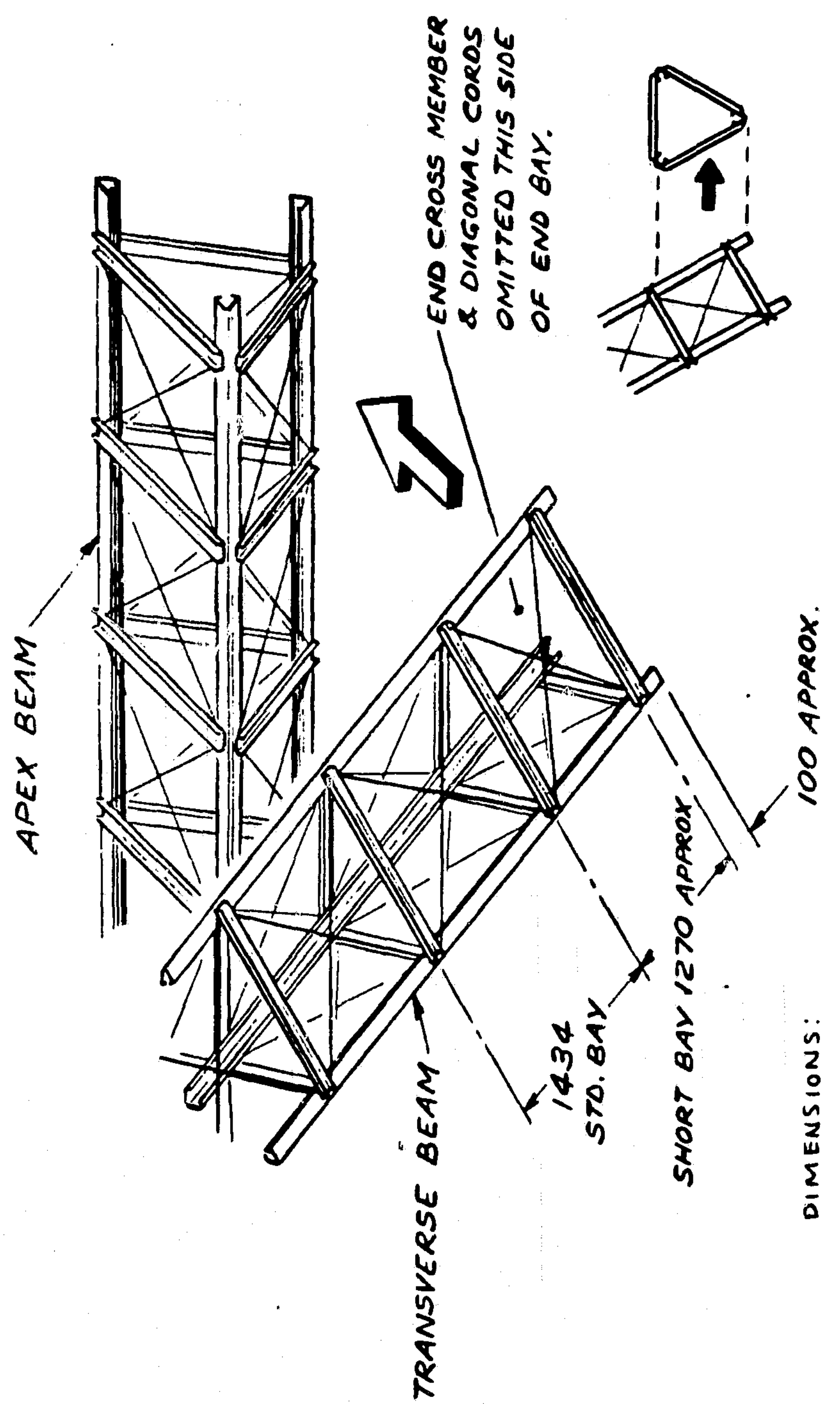
ACTIVITY 9.1

CONSTRUCTION ACTIVITY DATA SHEET
ATTACHMENT 1 (Page 1 of 3)

9.1 FABRICATE TRANSVERSE BEAM NO. 1

The following two pages illustrate proposed modifications of the baseline spacing of cross-members on the General Dynamics Space Fabricated Beam - at the ends of the transverse beams. The modifications are necessary to prevent interferences of ends of the transverse beams with each other or with the cross beams when all three of the beams are in the same plane at a given frame station along the longitudinals. Note that one side of the transverse beam end also has the last cross-member and the diagonal cords omitted. This prevents interference with the diagonal cords on the longitudinal beam at the interface.

PREPARED BY: J. ROEBUCK	Space Systems Group — Rockwell International	PAGE NO. OF
CHECKED BY:		ACTIVITY REPORT NO. 9.1
DATE: NOV. 20, 1979	FABRICATE TRANSVERSE BEAM NO. 1	MODEL NO. ETVP
REF.	ATTACHMENT 1 (PG 2 OF 3)	DWG. NO.



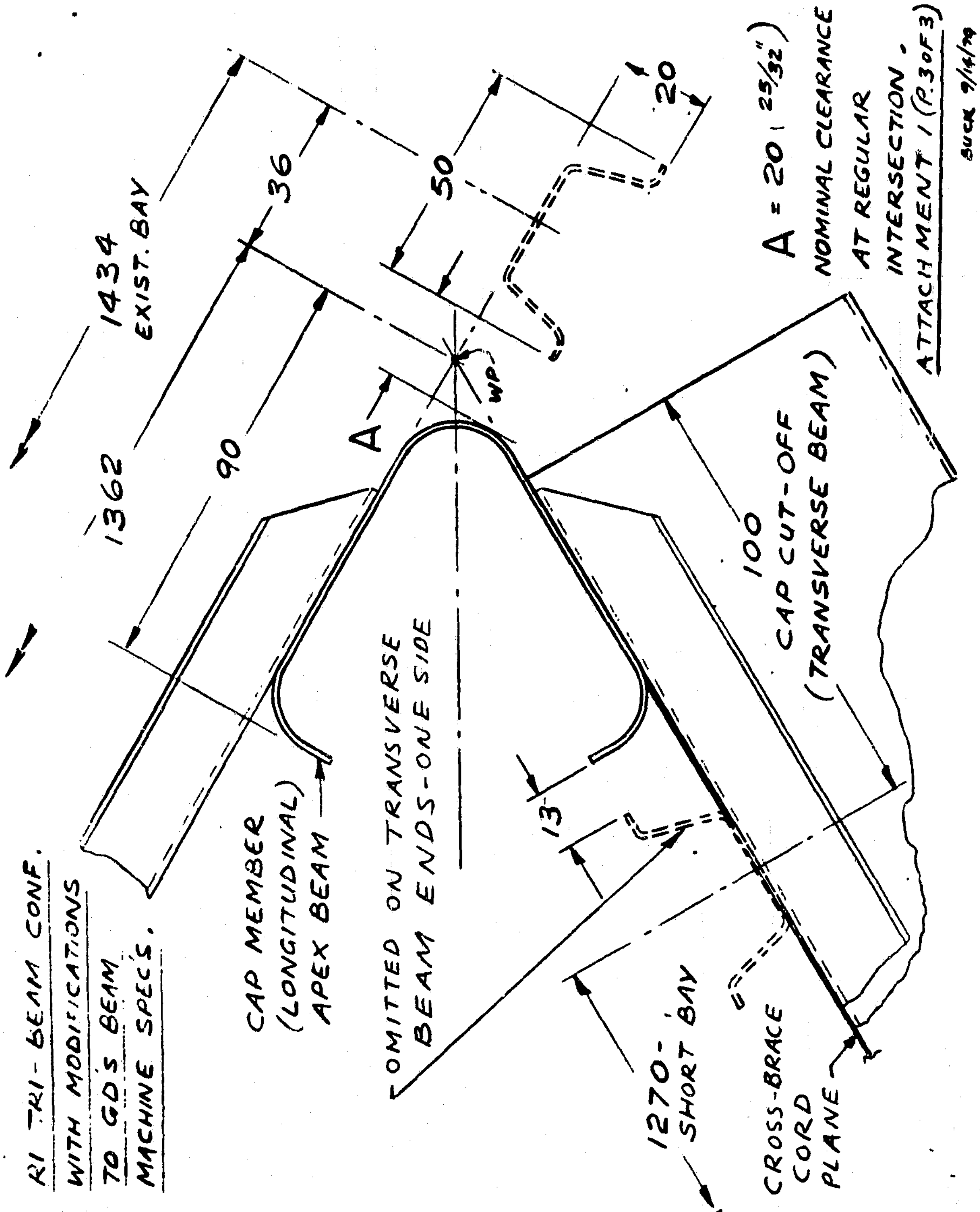
DIMENSIONS: MILLIMETERS

ATTACHMENT 1 (PAGE 2 OF 3)

II.1 FABRICATE TRANSVERSE BEAM NO. 1
DIMENSIONAL MODIFICATIONS-END BAY

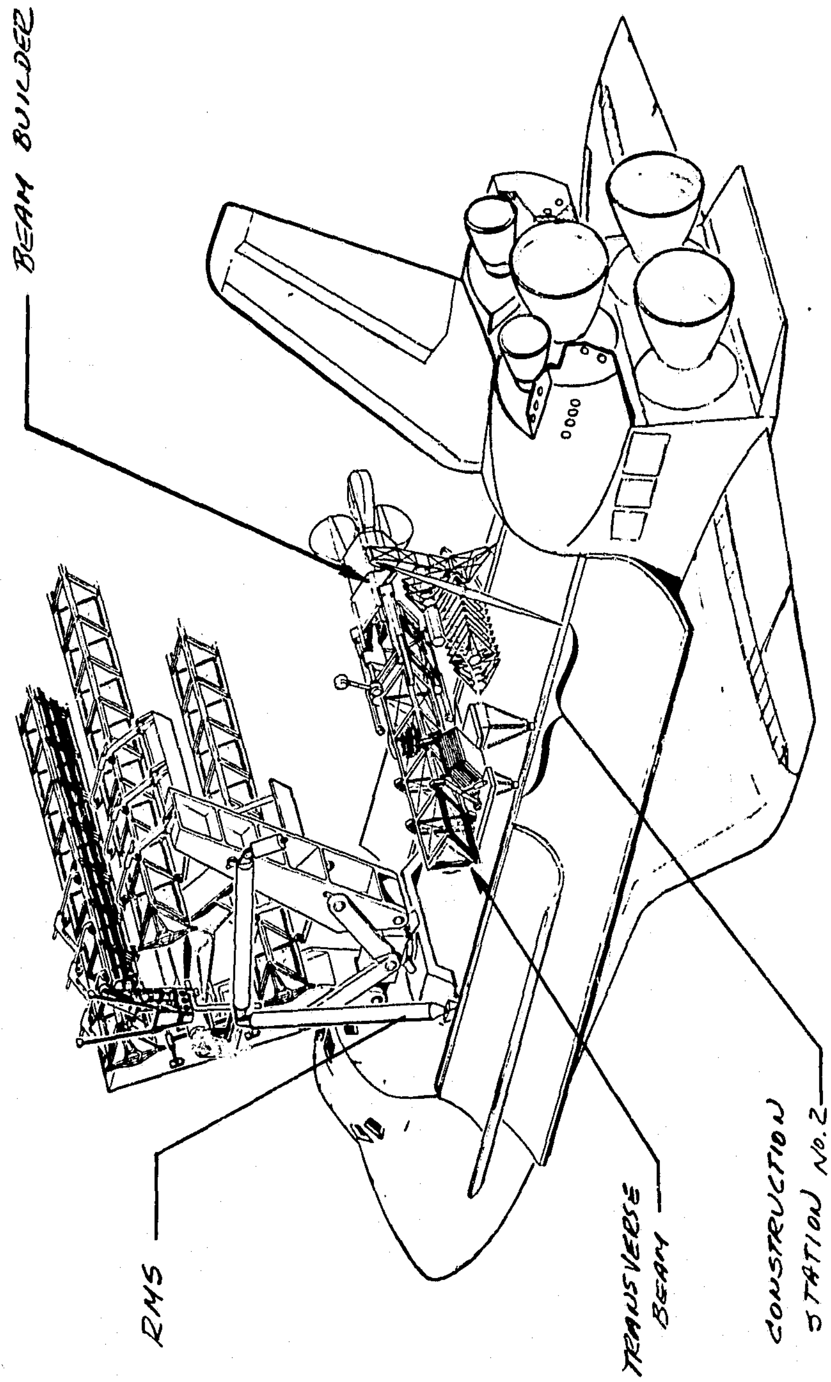
FORM 994-B-1 REV 12-78

J. ROEBUCK PREPARED BY:	Space Systems Group — Rockwell International	PAGE NO. OF
CHECKED BY:		ACTIVITY REPORT NO. 9.1
DATE: NOV. 20, 1979	FABRICATE TRANSVERSE BEAM NO. 1	MODEL NO. ETVP
REF.	ATTACHMENT 1 (PG. 3 OF 3)	DWG. NO.



FORM: 994-B-1 REV 12-78

PREPARED BY:	Space Systems Group — Rockwell International	PAGE NO. OF
CHECKED BY:		ACTIVITY 9.1 REPORT NO.
DATE:	FABRICATE TRANSVERSE BEAM	MODEL NO. ETVP
REF.	ATTACHMENT 2	DWG. NO.



FORM 994-B-1 REV 12-78

ACTIVITY 9.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

- 8.1 Relocate BB for Cross/Transverse Beam Fabrication
- 9.1 Fabr. Transverse Beam (No. 1)
- 10.0 Transport Transverse Beam (No. 1) & Position for Joining
- **9.2 Join Inter-Section Fittings to Transverse Beam (No. 1)**

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-52, No. 2 Construction Station

DESCRIPTION OF ACTIVITY

Two intersection fittings are automatically positioned and welded to the transverse beam at Construction Station No. 2. Activity is typical for all transverse beams and crossbeams.

CONSTRUCTION SUPPORT EQUIPMENT

Applicator for intersection fitting (see Attachment 1)

TIMELINE

38 seconds (see Attachment 2). *NOTE: This occurs in parallel with beam building. No additional time is consumed.*

POWER/ENERGY

Peak power, 1.0 kW; average power, 0.795 kW; energy, 30.2 kJ
(see Attachments 2 and 3)

CREW LOAD

None

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TECHNOLOGY DEVELOPMENT REQUIREMENTS

Material and welding techniques for intersection fittings

ACTIVITY 9.2

ATTACHMENT 2

Time, Power, and Energy Estimate for Joining of Intersection Fitting to Crossbeam No. 1

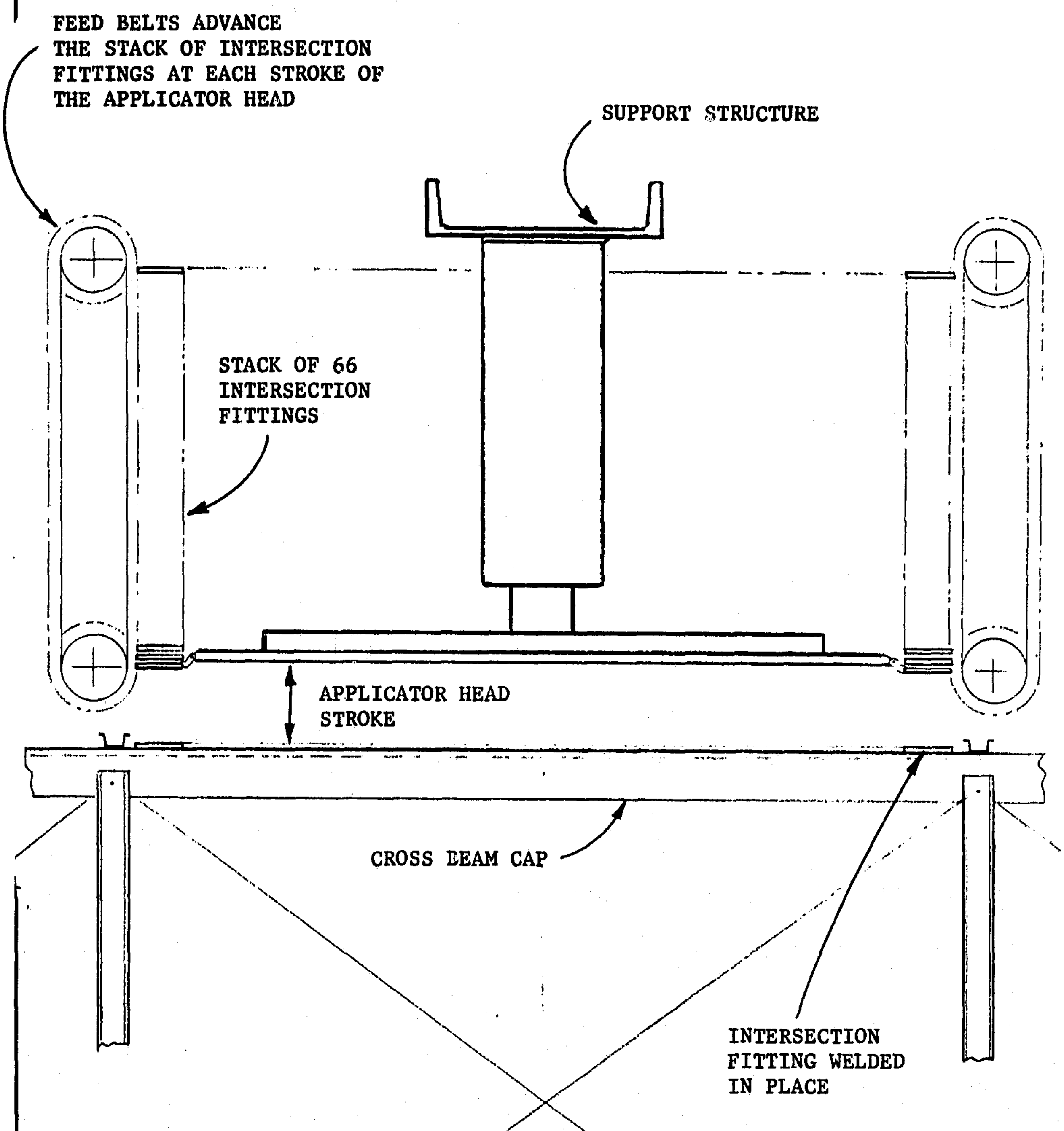
TASK DESCRIPTION	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. CROSSBEAM ADVANCES TO FIRST INTERESECTION POSITION.	N/A	N/A	N/A	N/A
2. PLUNGER DESCENDS WITH INTERSECTION FITTING AND CLAMPS IT TO THE CROSSBEAM.	2	-	0.025	0.05
3. WELD INTERSECTION FITTING TO CROSSBEAM. MEANWHILE, THE BELTS ON THE APPLICATOR ADVANCE THE SPACE OF ONE FITTING.	15	1	1	15
4. RETRACT THE PLUNGER AND GRASP THE NEXT FITTING IN THE STACK.	2	-	0.025	0.05
REPEAT STEPS 1, 2, 3, AND 4 TO JOIN THE SECOND FITTING TO THE CROSSBEAM.	19	1	-	15.1
NOTE: These operations each occur while the beam builder is halted for 40 seconds to install a crossmember.				
TOTAL	38	1*	0.795**	30.2

*PEAK POWER SUMMARY IS BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

**AVERAGE POWER = $\frac{\text{TOTAL ENERGY}}{\text{TOTAL ACTIVITY TIME}}$

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 9.2
DATE:	JOIN INTERSECTION FITTINGS TO TRANSFERSE BEAM (NO. 1)	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT NO. 1



FORM 994-B-1 REV 12-78

PREPARED BY: Roebuck	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 9.2
DATE: 1/24/80	JOIN INTERSECTION FITTINGS TO TRANSVERSE BEAMS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3

ENERGY ANALYSIS OF FUSION BONDING OF INTERSECTION FITTING TO CROSSBEAM OR TRANSVERSE BEAM

- Assume specific heat of material: 0.35
  Energy rate to heat: 0.35 1 Btu/lb/°F = 0.35 Btu/lb/°F
- Assume density of material is 0.05 lb/in^3
- Volume estimation:

  Since heating and clamping is performed under closely controlled conditions, only a small area of bond is required (as compared to later bonding to the longitudinal beams where pressure is applied by beam positioner). Assume actual heated volume is four spots, each 2 in. × 2 in. × 1/8 in.

  Volume is 4×2×2×1/8 = 2 in
- Weight is 0.05×2 = 0.10 lb

  $\therefore$ Energy per °F = 0.10×0.35 = 0.035 Btu/°F
- Assume temperature rise of 200°F
- Energy required is 200×0.035 = 7 Btu at 100% efficiency

  One Btu = 0.2931 watt-hour (Wh)

  $\therefore$ 7 Btu = 2.05 Wh
- Assume 50% heating efficiency. Then, energy required is 2×2.05 = 4.1 Wh or 4.1×60 = 246 watt-min.

  Assume heating is done in 15 sec = 0.25 min.
- Power = $\frac{246}{0.25}$ = 984 watts, say 1000 watts for working number

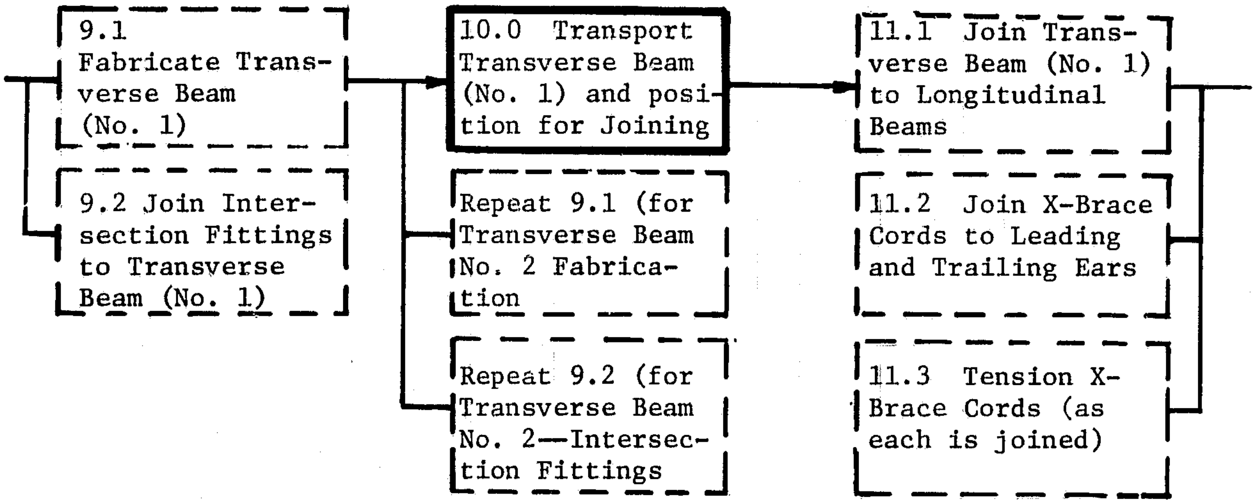
FORM 994-B-1 REV 12-78

ACTIVITY 10.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-50, Construction Fixture Assembly
3. Drawing 42662-55, EVA Work Station
4. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), Part III*, Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine).
5. *Space Shuttle System Payload Accommodations, Level II Program Definition and Requirements*, Volume XIV, JSC 07700, Rev. F, August 17, 1979.
6. *Performance Specification Manipulator Arm, Shuttle RMS*, SPAR-SG 366, Issue F, May 1978, Corrections through April 1979.

DESCRIPTION OF ACTIVITY

The modified RMS grasps and transports a transverse beam from Work Station No. 2 to within "capture range" of the beam positioner at Work Station No. 1 (see Attachment 1), releases the beam, and returns (as shown in Attachments 1 through 4). The beam positioner receives the transverse beam for joining to the longitudinal beams. The RMS is under control of the IVA operator. However, during the last five minutes an EVA astronaut will provide verbal/ visual feedback.

ACTIVITY 10.0 (Cont.)

CONSTRUCTION SUPPORT EQUIPMENT

1. Beam-builder machine (Reference 5)
2. Modified orbiter RMS with upper arm roll joint and special end effector (Reference 6)
3. Tri-beam construction fixture (Reference 3)

TIMELINE

41 minutes (see Attachments 4 and 5)

POWER/ENERGY

Peak power, 2.25 kW; average power, 1.6 kW; total energy, 3950 kJ (see Attachment 5)

CREW LOAD

IVA: 1.0 man, 41 minutes
EVA: 1.0 man, 5 minutes

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Roll joint for RMS upper arm (±100 degrees)
2. RMS end effector for grasping transverse beam
3. Beam positioner and position sensing system

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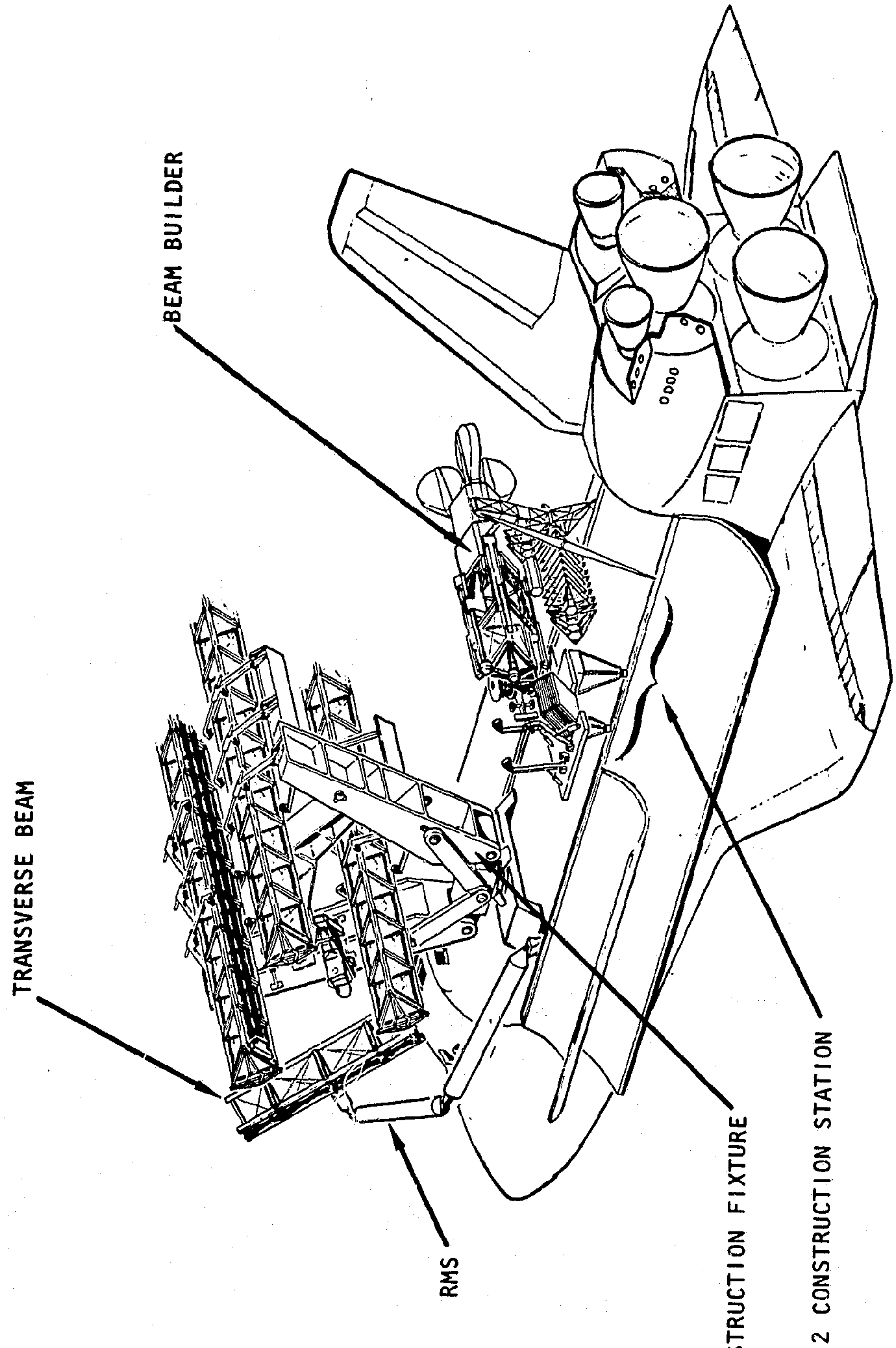
CHECKED BY:		ACTIVITY 10.0
DATE:	TRANSPORT TRANSVERSE BEAM (NO. 1) AND POSITION FOR JOINING	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1



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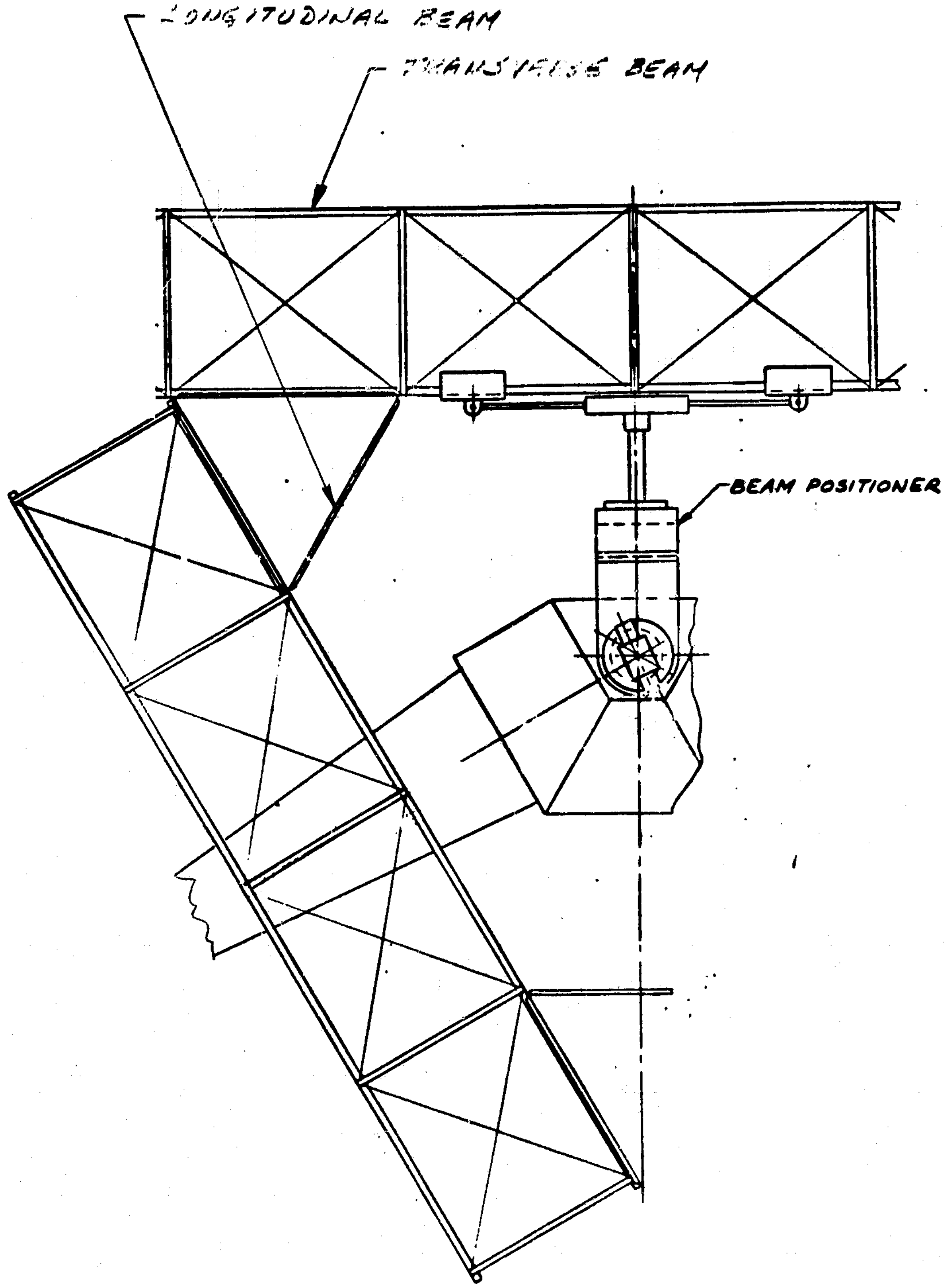
PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 10.0
DATE:	TRANSPORT TRANSVERSE BEAM (NO. 1) AND POSITION FOR JOINING	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



FORM 994-B-1 REV 12-78

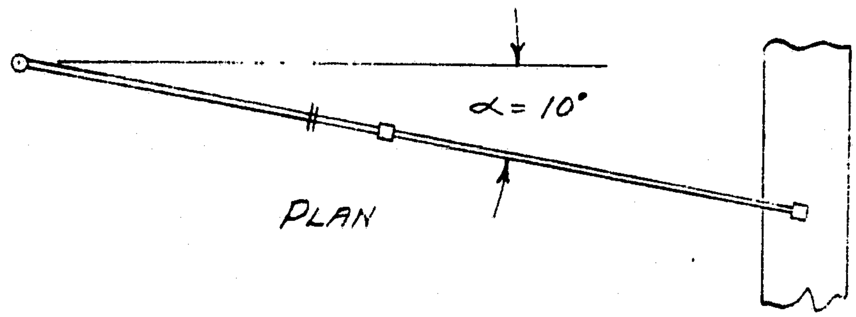
PREPARED BY: C. FRITZ	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 10.0
DATE: 11-28-79	TRANSPORT TRANSVERSE BEAM (NO. 1) AND POSITION FOR JOINING	MODEL NO. ETVP
		DWG. NO.

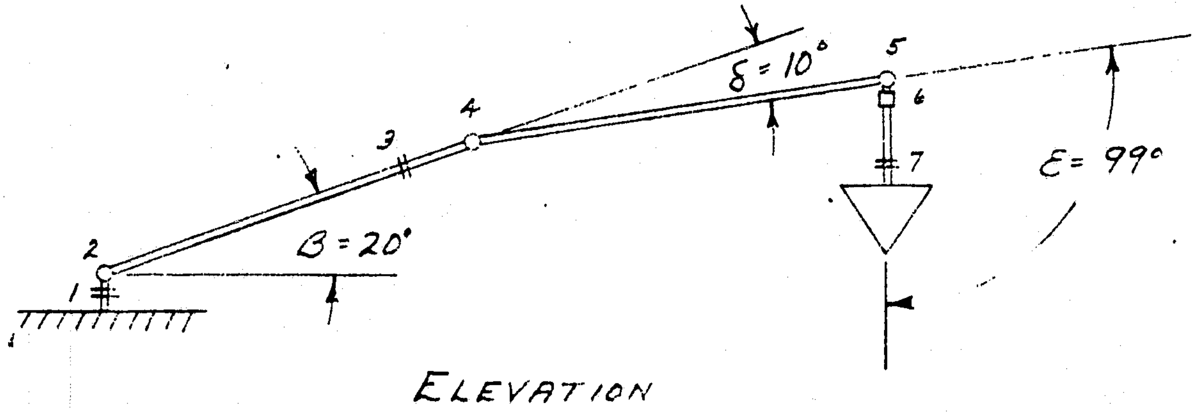
ATTACHMENT 3

RMS JOINT INITIAL SET-UP ANGLES

JOINT LEGEND

1. SHOULDER YAW
2. SHOULDER PITCH
3. UPPER ARM ROLL
4. ELBOW PITCH
5. WRIST PITCH
6. WRIST YAW
7. WRIST ROLL





FORM 994-B-1 REV 12-78

ATTACHMENT 4

ACTIVITY 10.0
TRANSPORT TRANSVERSE BEAM (NO. 1) AND POSITION FOR JOINING—SINGLE JOINT DRIVE MODE

	JOINT 1	JOINT 2	JOINT 3	JOINT 4	JOINT 5	JOINT 6	JOINT 7
INITIAL SETUP ANGLES →	$\alpha = 10°$ YAW	$\beta = 20°$ PITCH	$\gamma = 0°$ ROLL	$\delta = 10°$ PITCH	$\varepsilon = 99°$ PITCH	$\theta = 0°$ YAW	$\lambda = 0°$ ROLL
TRANSPORT STEPS							
1		10°					
2	100°						
3			150°				
4				60°			
5							150°
6				15°			
7					10°		
JOINT RATES (DEGREES/MINUTE)	13.74	13.74	13.74	19.26	28.56	28.56	28.56
TIME (MINUTES)	7.28	0.73	10.92	3.89	0.35	-	5.25
Σ TIME (MINUTES)	7.28	8.01	18.93	22.82	23.17	23.17	28.42

ACTIVITY 10.0

ATTACHMENT 5

TIME AND POWER SUMMARY

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. PWR. (kW)	ENERGY (kJ)
1. MOVE RMS TO POSITION	60	0.845 1.050†	0.845 0.525†	50.7 31.5
2. GRASP COMPLETED BEAM WITH RMS, RELEASE BEAM FROM BEAM BUILDER	180	0.845 1.050†	0.845 0.525†	152.1 94.5
3. TRANSPORT BEAM WITH RMS FROM BEAM BUILDER TO ASSEMBLY FIXTURE BEAM POSITIONER "ACCEPTANCE" LOCATION	1680	0.845 1.050†	0.845 0.525†	1419.6 882.0
4. GRASP BEAM WITH BEAM POSITONER; RELEASE RMS	120	0.845 1.050† 0.100††	0.845 0.525† 0.100††	101.4 63.0 12.0
5. RETURN RMS TO BEAM BUILDER LOCATION (USE 25% OF ITEM 3)	420	0.845 1.050†	0.845 0.525†	354.9 220.5
SIMULTANEOUS OPERATIONS (NON-ADDITIVE) LIGHTS, TV CAMERAS & HEATERS	(2460)	0.173 0.80	0.173 0.057	425.6 140.2
TOTALS	2460	2.248*	1.605**	3948

*PEAK POWER AND SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES SUBJECTIVELY ESTIMATED BEING PERFORMED SIMULTANEOUSLY.

$$**\text{AVERAGE POWER} = \frac{\text{ENERGY SUMMARY}}{\text{TOTAL ACTIVITY TIME}}$$

†HEATER
††BEAM POSITIONER

ACTIVITY 11.1

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

10.0 Transport Transv. Beam (No. 1) & Position for Joining	**11.1 Join Transverse Beam (No. 1) to Longitudinal Beams**	12.1 Transport Transverse Beam No. 2
Repeat 9.1 (for Transverse Beam No. 2 Fabrication)	11.2 Join X-Brace Cords to Leading & Trailing Ears	12.2 Fabricate Crossbeam
Repeat 9.2 (for Transverse Beam No. 2— Intersec. Fittings	11.3 Tension X-Brace Cords (as each is joined)	12.3 Install Attach Ports (to Crossbeam No. 1)

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Drawing 42662-50, Tri-Beam Construction Fixture
4. Drawing 42662-55, EVA Work Station

DESCRIPTION OF ACTIVITY

The activity begins after the beam positioner has grasped the transverse beam and the RMS has released it. The EVA astronaut waits until the RMS is clear of the area (approximately 30 sec), then activates the beam positioner (which automatically maneuvers the beam to joining position), and hold a slight closing pressure so the intersection fittings press firmly against the longitudinal beams (see Attachment 1). The EVA astronaut maneuvers to one joint, connects electrical power to fuse the bonding material of the intersection fitting at the interface to the longitudinal beam, and then does the same for the opposite joint. After the bond has cooled, the astronaut activates the beam positioner to exert a predetermined outward load to test the joint, releases and retracts the beam positioner, and then rotates and extends it to "ready" position for the next beam joining. This activity is typical for all transverse beams and crossbeams.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture (Ref. 4), including beam positioner
2. Cherry picker or positioning arm
3. Lighting and TV system

TIMELINE

17 minutes per beam (see Attachment 2)

ACTIVITY 11.1 (Cont.)

POWER/ENERGY

Peak power, 1.9 kW; average power, 1.3 kW; total energy, 1360 kJ (see Attachment 2)

CREW LOAD

Intermittant IVA: 0.5 man
EVA: one man, continuous

TECHNICAL DEVELOPMENT REQUIREMENTS

1. Development of material and methods for intersection fitting joining by electrical heating of interface material.

2. Control functions for beam positioner and EVA work station.

3. Modified open cherry picker compatible with limited work volume.

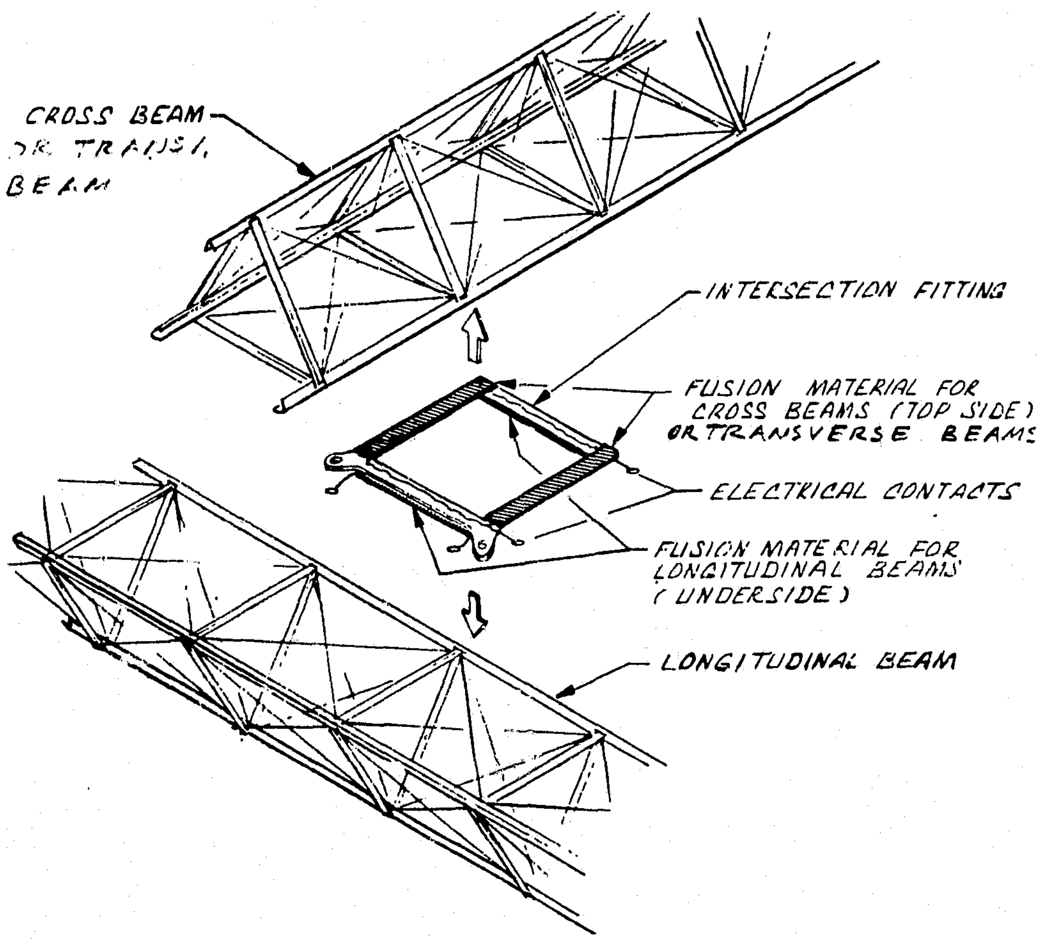
C-7

PREPARED BY: Roebuck/Fritz	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 11.1
DATE: 11 Dec. 1979	JOIN TRANSVERSE BEAM TO LONGITUDINAL BEAM	MODEL NO. ETVP
		DWG. NO. 42662-45

ATTACHMENT 1

INTERSECTION FITTING CONCEPT

The fitting is bonded to the transverse beam during fabrication and then to the longitudinal beam during joining of the transverse beam to the longitudinal beam. The activity is similar for joining crossbeams to longitudinal beams.



FORM 994-B-1 REV 12-78

ACTIVITY 11.1

ATTACHMENT 2

Duration, Power, and Energy Estimations for Joining Transverse Beam to Longitudinal Beams

TASK DESCRIPTION	DURATION (sec)	PEAK PWR (kW)	AVG. PWR (kW)	ENERGY (kJ)
1. WAIT UNTIL RMS IS CLEAR	30 (a)	0.4 (b)	0.3	9
2. POSITION BEAM FOR JOINING	90	0.5	0.4	36
3. MANEUVER EVA WORK STATION AND CONNECT ELECTR. POWER. (c)	120	0.5	0.4	48
4. HEAT INTERS. FITTING (c)	300	1.3	1.3	390
5. MANEUVERS TO SECOND JOINT STATION AND CONNECT ELECTR. POWER (TIME NON-ADDITIVE)	(150)	0.5	0.4	60
6. WAIT UNTIL FIRST JOINT HEATED (TIME NON-ADD.)	(150)	0.4	0.3	45
7. HEAT INTERSECT. FITTING	300	1.3† 0.4††	1.3† 0.3††	480
8. POWER OFF, LEADS REMOVED	30	0.4	0.3	9
9. MANEUVER EVA WORK STATION TO NEUTRAL POSITION	60	0.5	0.4	24
10. WAIT FOR COOLING AND PERFORM LOAD TEST	60	0.5	0.4	24
11. RETRACT BEAM POSITIONER	30	0.5	0.4	12
12. LIGHTS & TV ON CONSTR. FIXTURE (TIME NON-ADD.)	(1020)	0.233	0.223	227
SUMMARY	1020	1.933*	1.334**	1364

†HEATING ††CHERRY PICKER

(a) RMS PWR IS LISTED IN CONSTR. ACTIVITY ANALYSIS 10.0; TIME FOR 10.0 OVERLAPS TIME FOR ACTIVITY 11.1 DURING THIS 30-SEC PERIOD.

(b) ASSUME LIGHTING POWER FOR ASTRONAUT DETAIL TASKS INCLUDED IN CHERRY PICKER POWER (WHICH IS ASSUMED AS 200 W)

(c) SEE ATTACHMENT 3 FOR HEATING POWER ANALYSIS

*PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES SUBJECTIVELY ESTIMATED AS BEING PERFORMED SIMULTANEOUSLY.

**AVERAGE POWER = ENERGY SUMMATION/TOTAL ACTIVITY TIME

PREPARED BY: ROEBUCK	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 11.1
DATE:	JOIN TRANSVERSE BEAM (NO. 1) TO LONGITUDINAL BEAMS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3

ENERGY ANALYSIS OF FUSION BONDING FOR INTERSECTION FITTINGS

Assumed *specific heat* of material: 0.35

Actual energy rate to heat: 0.35 × 1 Btu/lb/°F = 0.35 Btu/lb/°F

Assume 0.05 $lb/in.^3$ *density of material*

0.05 × 50.75 $in.^3 \cong$ 2.54 lb weight

∴ Energy per °F = 2.54×0.35 = 0.89 Btu/°F

Assume *temperature rise*: 200°F. Energy is 200×0.89 = 178 Btu to bond joint at 100-percent eff. 1 Btu = .2931 Wh.

∴ 178 Btu = 52.2 Wh

Assume 50% efficiency input of heat. Then, energy required is 104 Wh, or 104 Wh×60 = 6240 W-min. If heating is done in 5 minutes*, power required is 6240 ÷ 5 = 1248 W, say 1.3 kW.

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*Assumed reasonable waiting time for EVA astronaut, compatible with beam fabrication times.

FORM 994-B-1 REV 12-78

ACTIVITIES 11.2 & 11.3

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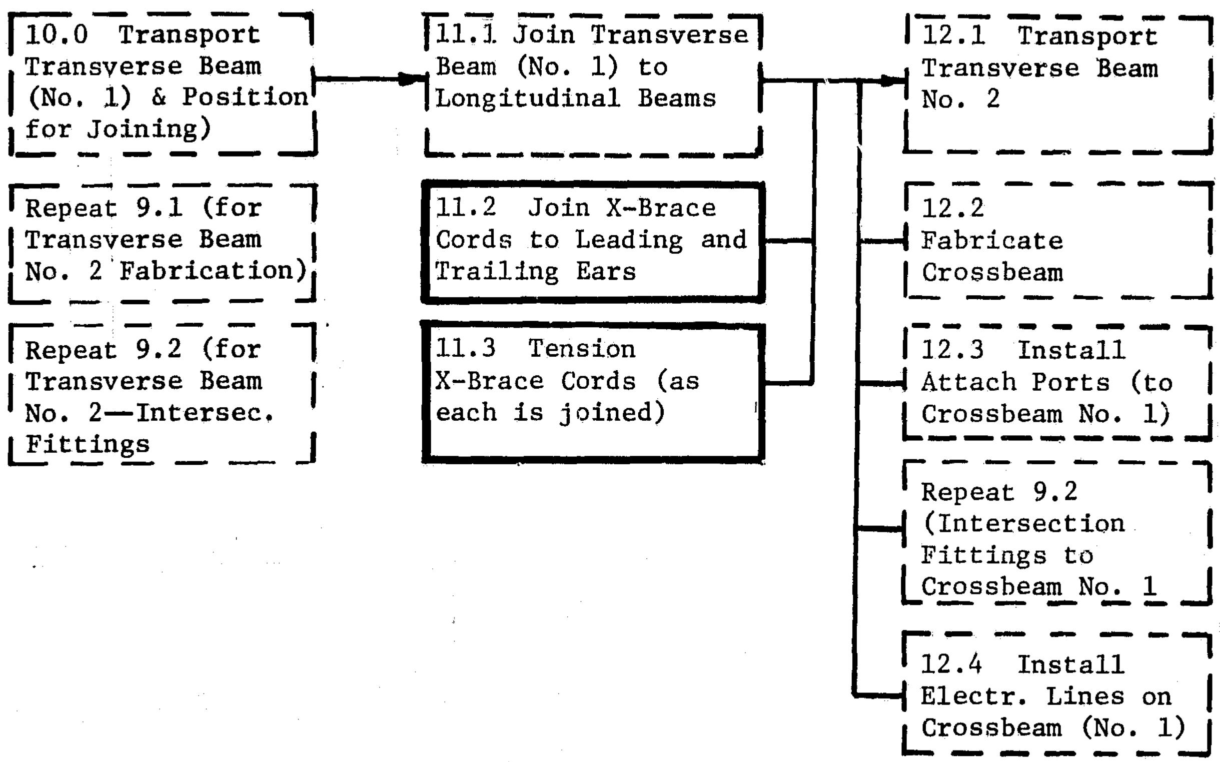
CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, Engineering and Technology Verification Platform
2. Space Construction Data Base
3. Drawing 42662-50, Tri-Beam Construction Fixture
4. Drawing 42662-55, EVA Work Station

DESCRIPTION OF ACTIVITY

After joining each transverse beam (or crossbeam), the EVA astronaut performs crossover and hookup of one pair of X-brace cords, according to crew positions and procedures in Attachments 1, 2, 3, and 4. (*Note: beam positioner is first relocated to next joining position, thus providing astronaut maneuvering space.*) Tensioning of each cord follows its hookup procedure. The first cord is tensioned to 6.4 N (15 lb), and the second cord is tensioned to the final load of 2355 N (530 lb), which creates the same load on the first cord. Tension is applied by a special torquing tool designed for use with the turnbuckle/hook device at the end of each X-brace cord (see Attachment 5). This activity is typical for all transverse beams and crossbeams, except the first and last frame set (see discussion, Attachment 1).

ACTIVITIES 11.2 AND 11.3
(Cont.)

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture (Reference 1)
2. X-brace cord dispensing system (See Attachment 1 and Reference 1 and 5)
3. Astronaut cherry picker and maneuvering arm (EVA work station) per Reference 5 and Attachment 1
4. Torque tool and turnbuckle device (see Attachment 4)

TIMELINE

Refer to Attachments 1 and 2; 16 minutes per pair of X-brace cords

POWER/ENERGY

Peak power, 0.5 kW; average power, 0.3 kW; energy, 314 kJ
(see Attachment 6)

CREW LOAD

EVA: 1.0 man continuously
IVA: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Astronaut cherry picker and maneuvering arm
2. X-brace cord dispensing system
3. Torque tool and turnbuckle device

PREPARED BY: Roebuck	Satellite Systems Division, Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 11.2
DATE: 1/28/80	JOIN X-BRACE CORDS TO LEADING AND TRAILING EARS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

DISCUSSION

The cross-brace cords are contained on six reels which are attached to the central structure of the construction fixture. The cords are prefabricated in segments of the appropriate length (plus a small allowance for takeup) to reach across the diagonal distance of a bay between frames. Each cord has a simple hook at one end which attaches to the so-called trailing ear of an intersection fitting. The other end of the cord has a combination hook and turnbuckle which is attached to the leading ear of another intersection fitting. The turnbuckle is actuated, as indicated in Attachment 4, to a desired tension prior to operation.

When the cords are wound around the reels, they are interconnected end-to-end by their hooks.

After joining the first transverse beam to the longitudinal beams, the EVA astronaut grasps the end of one cord from a reel and hooks it to the trailing ear of one of the intersection fittings. Then, he repeats this for the next intersection fitting. These actions are repeated for each of the three beams of the first frame set. When the platform assembly translates, it pulls the six cords out from their storage reels. Subsequently, the astronaut performs the activities, described in Attachment 3, as follows:

First, the hooks connecting the extended cord and the reeled cords are disconnected and retained under control of the astronaut on the cherry picker. A short length of tether is carried by the EVA astronaut for this purpose. The end of the cord, still wound on the reel, is attached to the trailing ear of the appropriate intersection fitting (Point B in Attachment 2). The tether is then released from this cord and the other cord end is carried across to the intersection fitting at the opposite side of the beam. There, it is hooked to the leading ear of the intersection fitting; then, the cord is tensioned. The tether is then released and the hookup sequence is repeated in the opposite sense. Thus, the two cords (which were unrolled during the translation of the assembly into a position roughly parallel to the longitudinal beams) are now crossed and fully tensioned in a plane parallel to the recently installed crossbeam or transverse beam. This sequence is repeated for each beam.

PREPARED BY: C. FRITZ	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES 11.2, 11.:
DATE: 12/5/79	11.2 JOIN X-BRACE CORDS 11.3 TENSION X-BRACE CORDS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

OPERATION	DISTANCE (FT)	TIME (MIN)
0. ASTRONAUT IN NEUTRAL POSITION	-	-
1. RELOCATE BEAM POSITIONER	-	1.00
2. GO TO POINT A	8.5	0.85
3. DISCONNECT TWO HOOKS	-	1.00
4. GO TO POINT B	3.0	0.30
5. CONNECT REEL CORD B	-	1.00
6. GO TO POINT F	10.0	1.00
7. CONNECT DIAGONAL CORD F	-	1.00
8. TENSION CORD F TO 14.4 LB	-	2.00
9. GO TO POINT D	1.7	0.17
10. DISCONNECT TWO HOOKS	-	1.00
11. GO TO POINT E	3.0	0.30
12. CONNECT REEL CORD E	-	1.00
13. GO TO POINT C	10.0	1.00
14. CONNECT DIAGONAL CORD C	-	1.00
15. TENSION CORD C TO 530 LB	-	2.00
16. GO TO NEUTRAL POSITION	10.0	1.00
TOTAL		15.62

NOTES

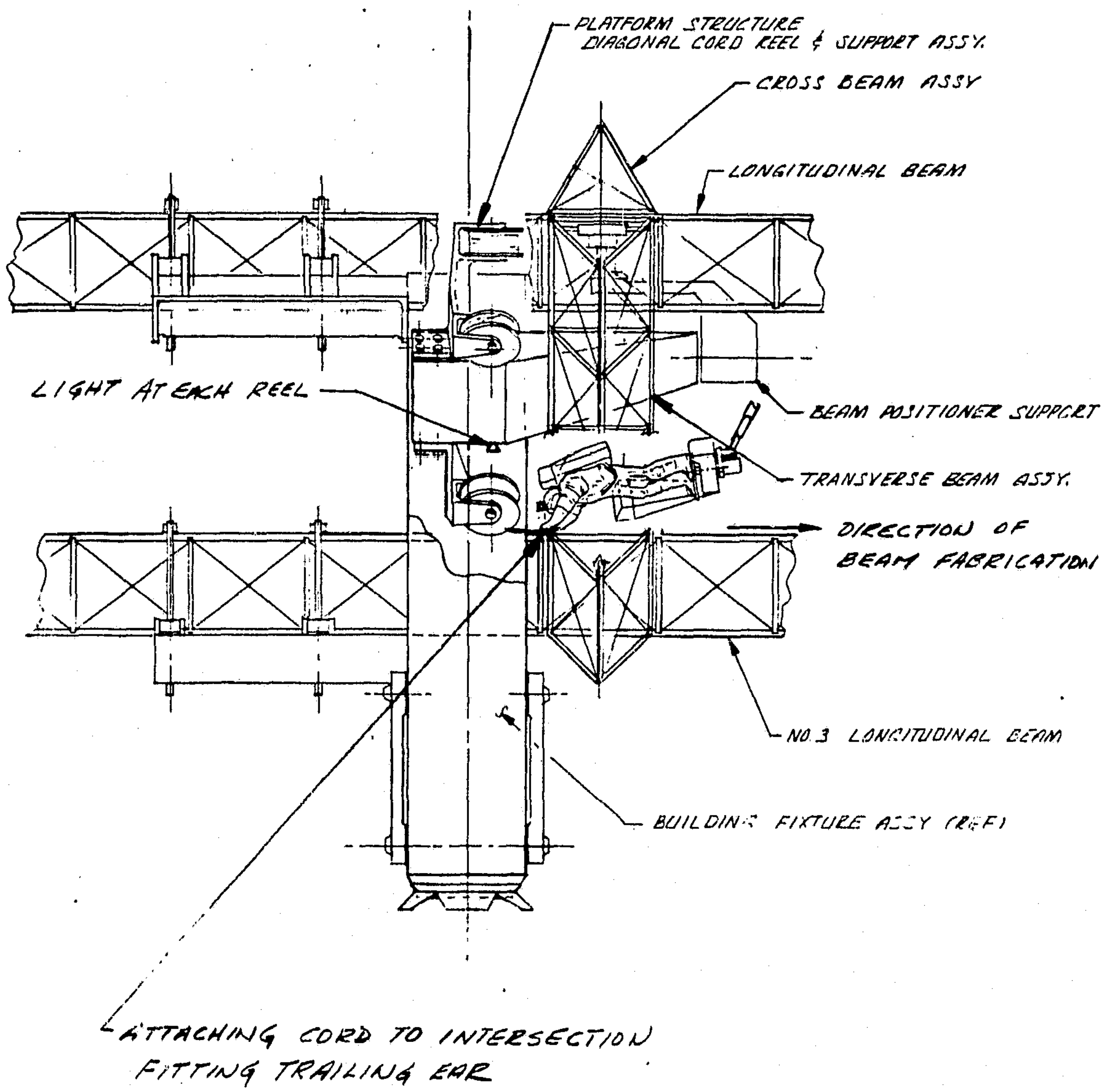
1 RATE OF ASTRONAUT MOVEMENT ESTIMATED TO BE 10 FT/MIN = 3.04 M/MIN

2 INSTALLATION OF X-BRACE CORD PAIRS H AND L, AND P AND S, TO BE SIMILAR TO ABOVE.

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES 11.2,11.3
DATE:	11.2 JOIN X-BRACE CORDS 11.3 TENSION X-BRACE CORDS	MODEL NO. ETVP
		DWG. NO.

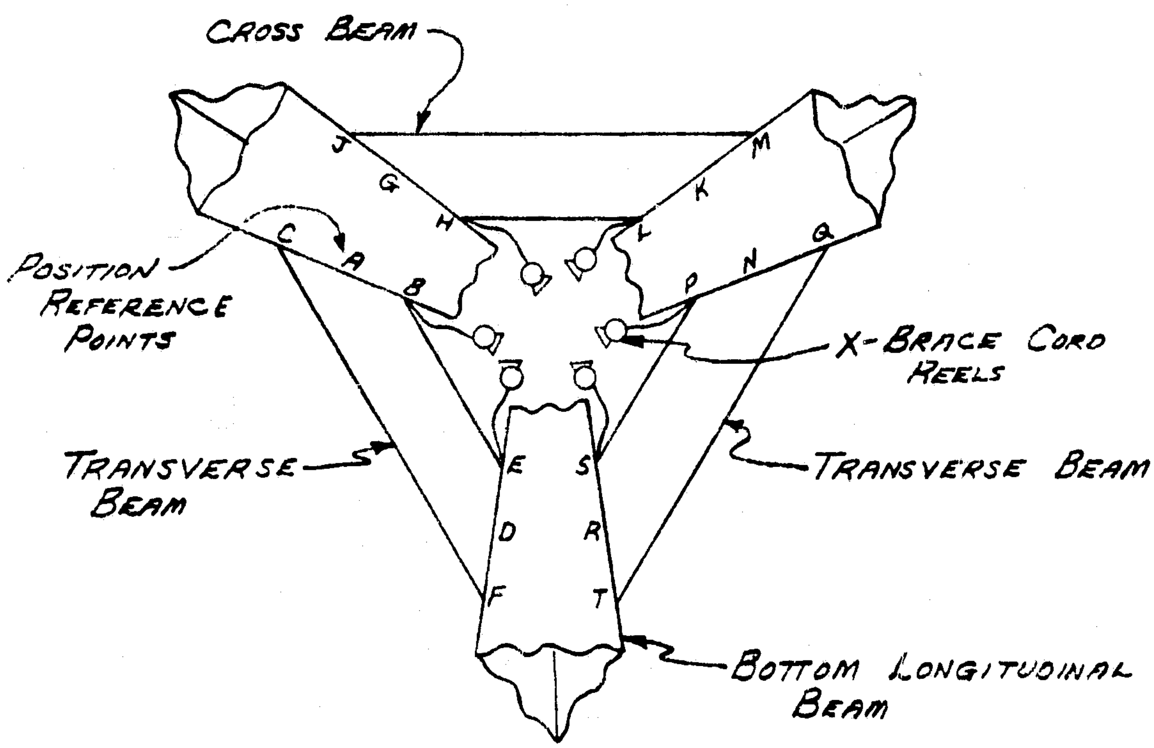
ATTACHMENT 3



FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES: 11.2 & 11.3
DATE:	11.2 JOIN X-BRACE CORDS 11.3 TENSION X-BRACE CORDS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 4



VIEW A-A

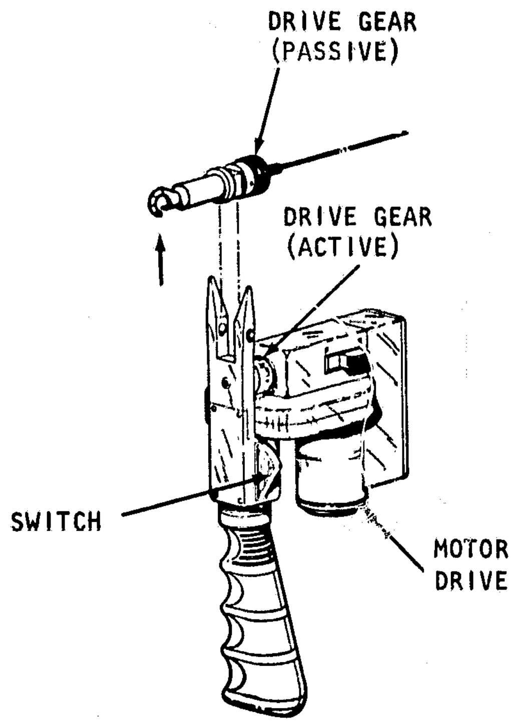
(REF. ATTACHMENT NO. 1)

FORM 994-B-1 REV 12-78

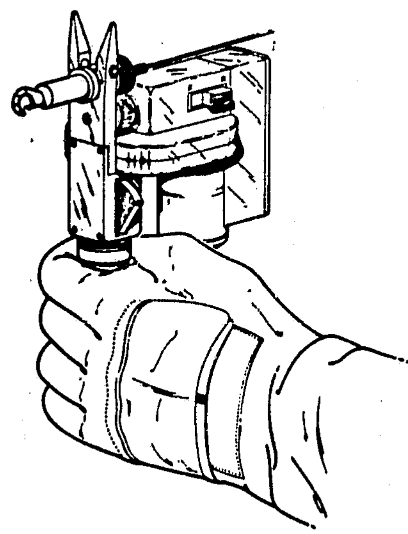
PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES 11.2 & 11.3
DATE:	11.2 JOIN X-BRACE CORDS 11.3 TENSION X-BRACE CORDS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 5

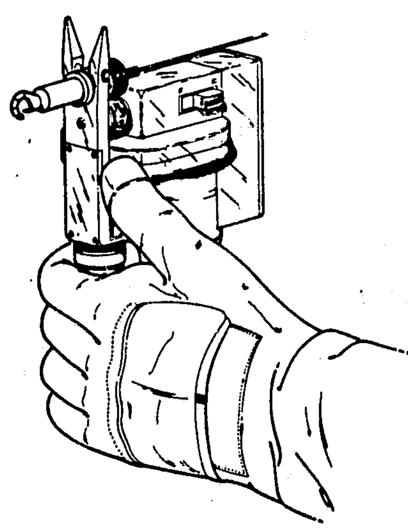
ORIGINAL PAGE IS OF POOR QUALITY



STEP 1
ATTACH TENSIONER



STEP 2



STEP 3
ACTUATE TENSIONING DRIVE SYSTEM

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITIES: 11.2 & 11.3
DATE:	JOIN X-BRACE CORDS AND TENSION	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 6

DURATION, POWER, AND ENERGY ESTIMATIONS FOR ATTACHING AND TENSIONING X-BRACE CORDS

OPERATION	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. RELOCATE BEAM POSITIONER	60	0.5	0.4	24
2. GO TO POINT A	51	0.5	0.4	20
3. DISCONNECT TWO HOOKS	60	0.4	0.3	18
4. GO TO POINT B	18	0.5	0.4	7
5. CONNECT REEL CORD B	60	0.4	0.3	18
6. GO TO POINT F	60	0.5	0.4	24
7. CONNECT DIAG. CORD F	60	0.4	0.3	18
8. TENSION CORD F	120	0.4	0.3	36
9. GO TO POINT D	10	0.5	0.4	4
10. DISCONNECT TWO HOOKS	60	0.4	0.3	18
11. GO TO POINT E	18	0.5	0.4	7
12. CONNECT REEL CORD E	60	0.4	0.3	18
13. GO TO POINT C	60	0.5	0.4	24
14. CONNECT DIAG. CORD C	60	0.4	0.3	36
15. TENSION CORD C	120	0.4	0.3	36
16. GO TO NEUTRAL	60	0.5	0.4	24
SUMMARY	937	0.5*	0.33**	314

NOTE: POWER ESTIMATES INCLUDE 0.180 kW FOR LIGHTS ON CHERRY PICKER

*PEAK POWER IS HIGHEST OF INDIVIDUAL TASK PEAKS

$$\text{**AVERAGE POWER} = \frac{\text{ENERGY SUMMARY}}{\text{TOTAL ACTIVITY TIME}}$$

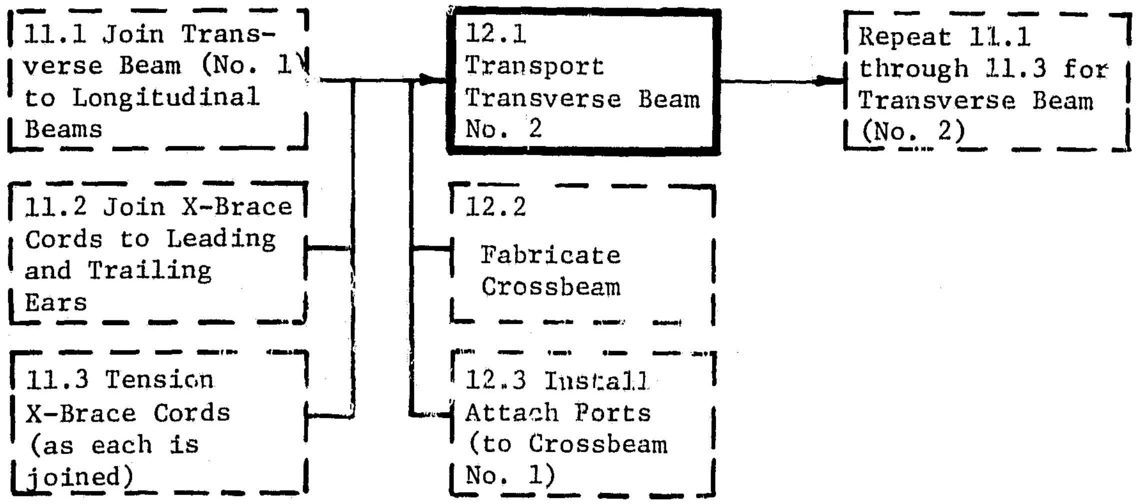
FORM 994-B-1 REV 12-78

ACTIVITY 12.1

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Space Construction Data Base

2. Drawing 42662-50, Construction Fixture
3. Drawing 42662-55, EVA Work Station
4. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), Part III*, Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine).
5. *Space Shuttle System Payload Accommodations, Level II Program Definition and Requirements*, Volume XIV, JSC 07700, Revision F, August 17, 1979.
6. *Performance Specification Manipulator Arm, Shuttle RMS*, SPAR-SG 366, Issue F, May, 1978, Corrections through April 1979.

DESCRIPTION OF ACTIVITY

The modified RMS grasps and transports a transverse beam from Work Station No. 2 to within "capture range" of the beam positioner at Work Station No. 1, releases the beam, and returns (as shown in Attachments 1 through 4). The beam positioner receives the transverse beam for joining to the longitudinal beams. The RMS is under control of the IVA operator. However, during the last five minutes, an EVA astronaut provides verbal/visual feedback.

ACTIVITY 12.1

CONSTRUCTION SUPPORT EQUIPMENT

1. Beam-builder machine (Reference 5)
2. Modified orbiter RMS with upper arm roll joint and special end effector (Reference 6)
3. Tri-beam construction fixture (Reference 3)

TIMELINE

30 minutes (see Attachments 4 and 5)

POWER/ENERGY

Peak power, 2.25 kW; average power, 1.606 kW, energy 2892 kJ (see Attachment 5)

CREW LOAD

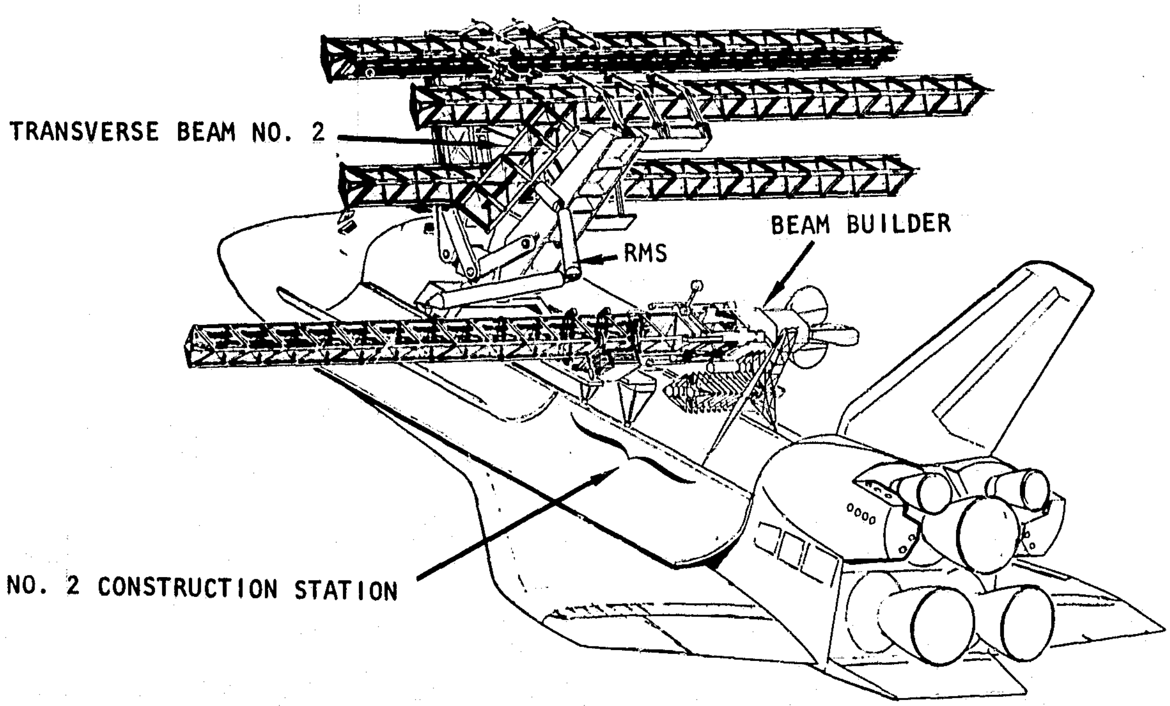
IVA: 1.0 man, 30 minutes
EVA: 1.0 man, 5 minutes

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Roll joint for RMS upper arm (±100°)
2. RMS end effector for grasping transverse beam
3. Beam positioner and position sensing system

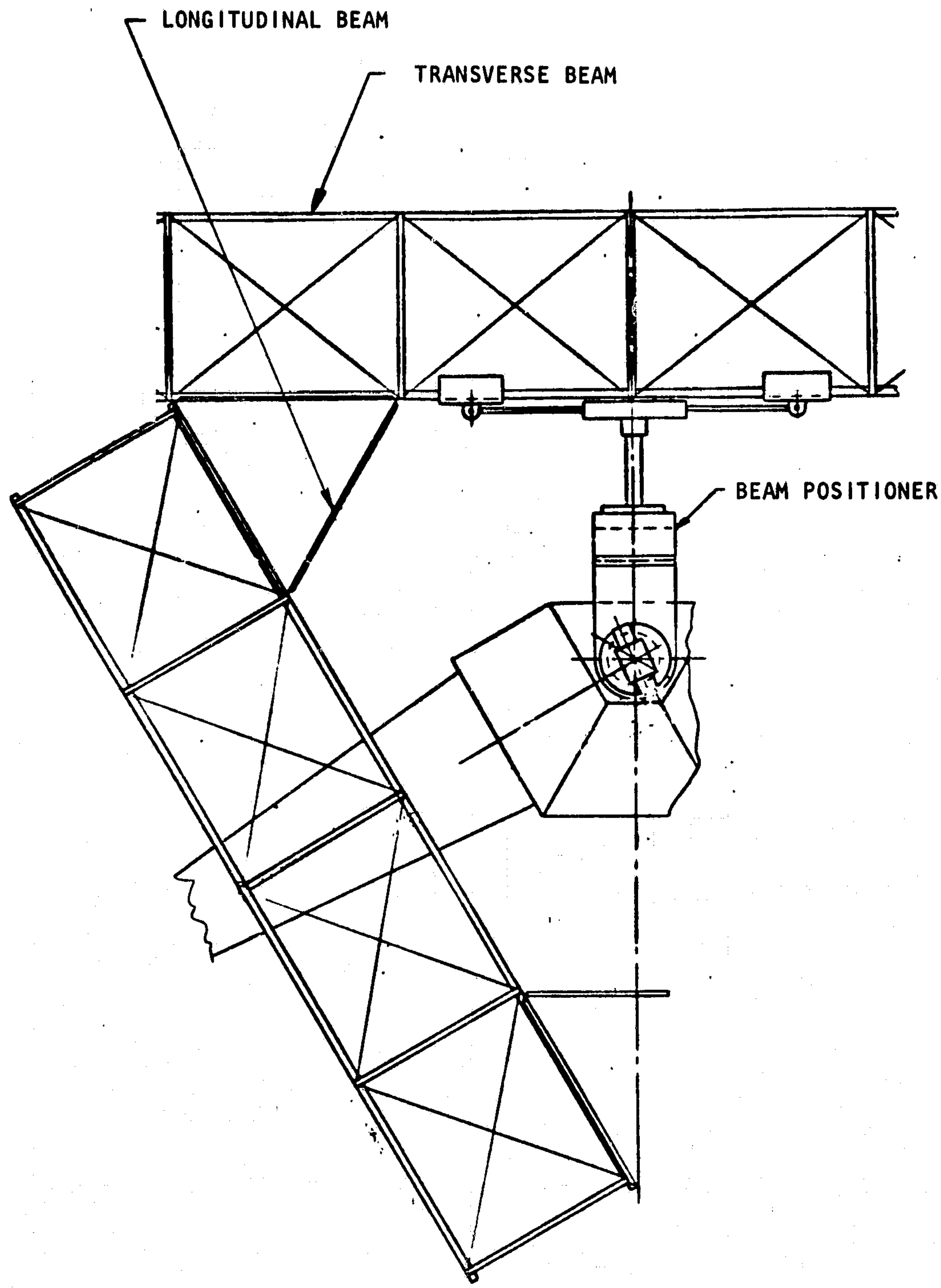
PREPARED BY: C. FRITZ	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.1
DATE: 11-29-79	TRANSPORT TRANSVERSE BEAM NO. 2	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1



FORM 324-B-1 REV 12-78

ATTACHMENT 2



FORM 994-B-1 REV 12-78

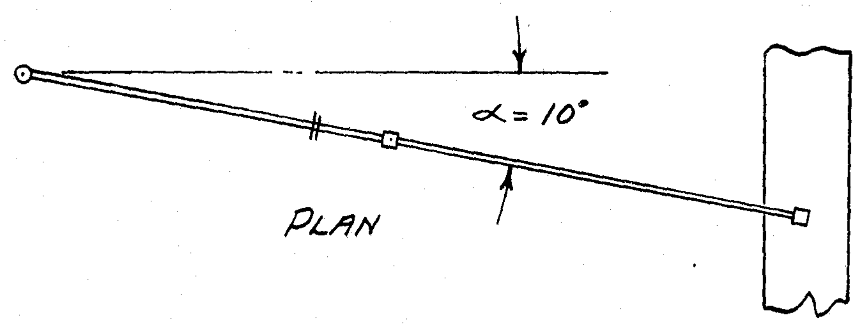
PREPARED BY: C.H. FRITZ	Space Systems Group — Rockwell International	PAGE NO. OF
CHECKED BY:		REPORT NO. 12.1
DATE: 11-29-79	TRANSPORT TRANSVERSE BEAM NO. 2 AND POSITION FOR JOINING	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT No. 3

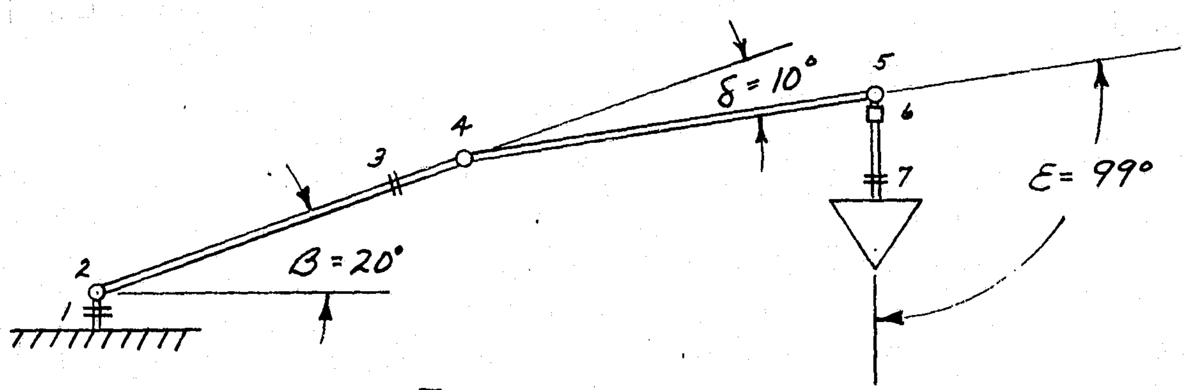
RMS JOINT INITIAL SETUP ANGLES

JOINT LEGEND

1. SHOULDER YAW
2. SHOULDER PITCH
3. UPPER ARM ROLL
4. ELBOW PITCH
5. WRIST PITCH
6. WRIST YAW
7. WRIST ROLL



PLAN



ELEVATION

FORM 994-B-1 REV 12-78

ATTACHMENT 4

ACTIVITY 12.1
TRANSPORT TRANSVERSE BEAM (NO. 2) AND POSITION FOR JOINING—SINGLE JOINT DRIVE MODE

	JOINT 1	JOINT 2	JOINT 3	JOINT 4	JOINT 5	JOINT 6	JOINT 7
INITIAL SETUP ANGLES →	α = 10° YAW	β = 20° PITCH	γ = 0° ROLL	δ = 10° PITCH	ϵ = 99° PITCH	θ = 0° YAW	λ = 0° ROLL
TRANSPORT STEPS							
1		30°					
2							180°
3						90°	
4	20°						
5			30°				
6				50°			
7						30°	
8	20°						
JOINT RATES (DEGREES/MINUTE)*	13.74	13.74**	13.74	19.26	28.56	28.56	28.56
TIME (MINUTES)	2.91	2.18	2.18	2.60	-	4.20	6.30
Σ TIME (MINUTES)	2.91	5.09	7.27	9.87	-	14.07	20.37

*PER REFERENCE 6, pp. 3-39, JOINT RATE MAXIMUM.
**ASSUMED VALUE FOR PROPOSED ADDITIONAL RMS JOINT.

ACTIVITY 12.1

ATTACHMENT 5

TIME AND POWER SUMMARY

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. PWR. (kW)	ENERGY (kJ)
1. MOVE RMS TO POSITION				
2. GRASP COMPLETED BEAM WITH RMS, RELEASE BEAM FROM BEAM BUILDER	180	0.845 1.050†	0.845 0.525†	152.1 94.5
3. TRANSPORT BEAM WITH RMS FROM BEAM BUILDER TO ASSEMBLY FIXTURE BEAM POSITIONER "ACCEPTANCE" LOCATION	1200	0.845 1.050†	0.845 0.525†	1014.0 630.0
4. GRASP BEAM WITH BEAM POSITONER; RELEASE RMS	1200	0.845 1.050† 0.100††	0.845 0.525† 0.100††	101.4 63.0 12.0
5. RETURN RMS TO BEAM BUILDER LOCATION (USE 25% OF ITEM 3)	300	0.845 1.050†	0.845 0.525†	253.5 157.5
SIMULTANEOUS OPERATIONS (NON-ADDITIVE) LIGHTS, TV CAMERAS & HEATERS	(1800)	0.173 0.80	0.173 0.057	311.4 102.6
TOTALS	1800	2.248*	1.606**	2892.0

*PEAK POWER AND SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

**AVERAGE POWER = $\frac{\text{ENERGY SUMMARY}}{\text{TOTAL ACTIVITY TIME}}$

†HEATER
††BEAM POSITIONER

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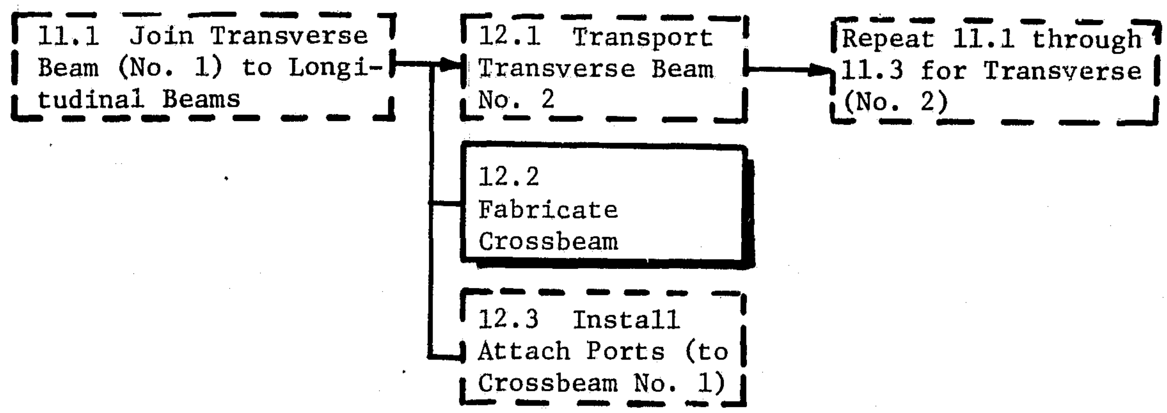
ACTIVITY 12.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS)*, Part III Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine).
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Space Construction Data Base
4. Drawing 42662-72, Attach Port
5. Drawing 42662-52, No. 2 Construction Station
6. Construction Activity Data Sheet: 12.3—*Install Attachment Ports*

DESCRIPTION OF ACTIVITY

Begins with initial heating of cap material and continues until cutoff of beam and separation from beam machine a sufficient distance to permit joining of attachment port on end (per References 4, 5, and 6). Fabrication methods are discussed in Reference 1, with modifications per Attachment 1 (pertinent to end stub length). Beam is supported at Work Station No. 2 construction fixture per Reference 5 (see Attachment 2). Beam fabrication rates are per Reference 1, but first joining of attachment port and joining of two intersection fittings interrupt beam building. The basic fabrication activity is typical for all crossbeams, but timelines vary for short and long crossbeams.

ACTIVITY 12.2 (Cont.)

CONSTRUCTION SUPPORT EQUIPMENT

1. Work "ion No. 2 construction fixture system (Reference 5)
2. Lighting ar TV system (see Construction Activity Data Sheet 3.1)
3. Beam-builder machine (per Reference 1)

TIMELINE (see Section 5.3)

1.08 meters/minute (Reference 5); 16.1 minutes for 17.4 meters (long crossbeam); 7.8 minutes for 8.4 meters (short crossbeam)

POWER/ENERGY (see Section 5.3)

Beam builder: 2.242 kW, average; 3.546 kW, peak; 179.2 kJ/bay;
2509 kJ for long crossbeam, 1075 kJ for short crossbeam

Lighting: 200 W

TV with heater: 23 W average, 33 W peak

CREW LOAD

IVA: Approximately 0.5 man continuously monitoring
EVA: None

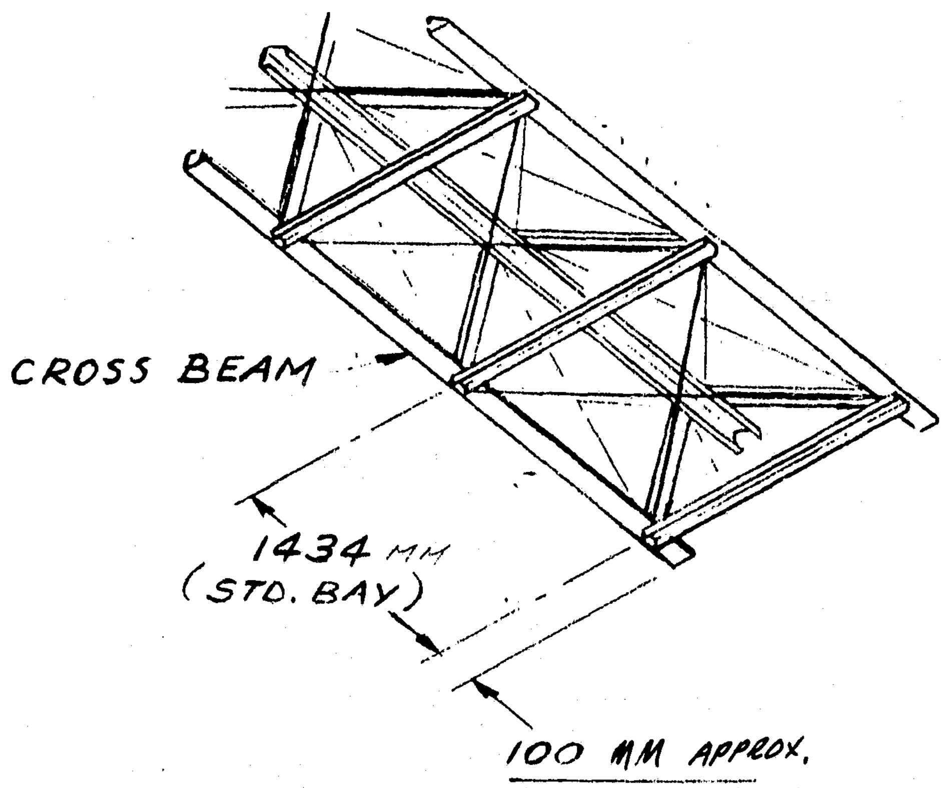
TECHNOLOGY DEVELOPMENT REQUIREMENTS

Development of beam builder

PREPARED BY: J. ROEBUCK	Space Systems Group Rockwell International	PAGE NO. OF
CHECKED BY:		ACTIVITY REPORT NO. 12.2
DATE: 4 DEC 1979	FABRICATE CROSS BEAM	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 1

BEAM END MODIFICATION TO GENERAL DYNAMICS FABRICATED BEAM BASELINE (TYPICAL FOR LONG AND SHORT CROSS BEAMS)



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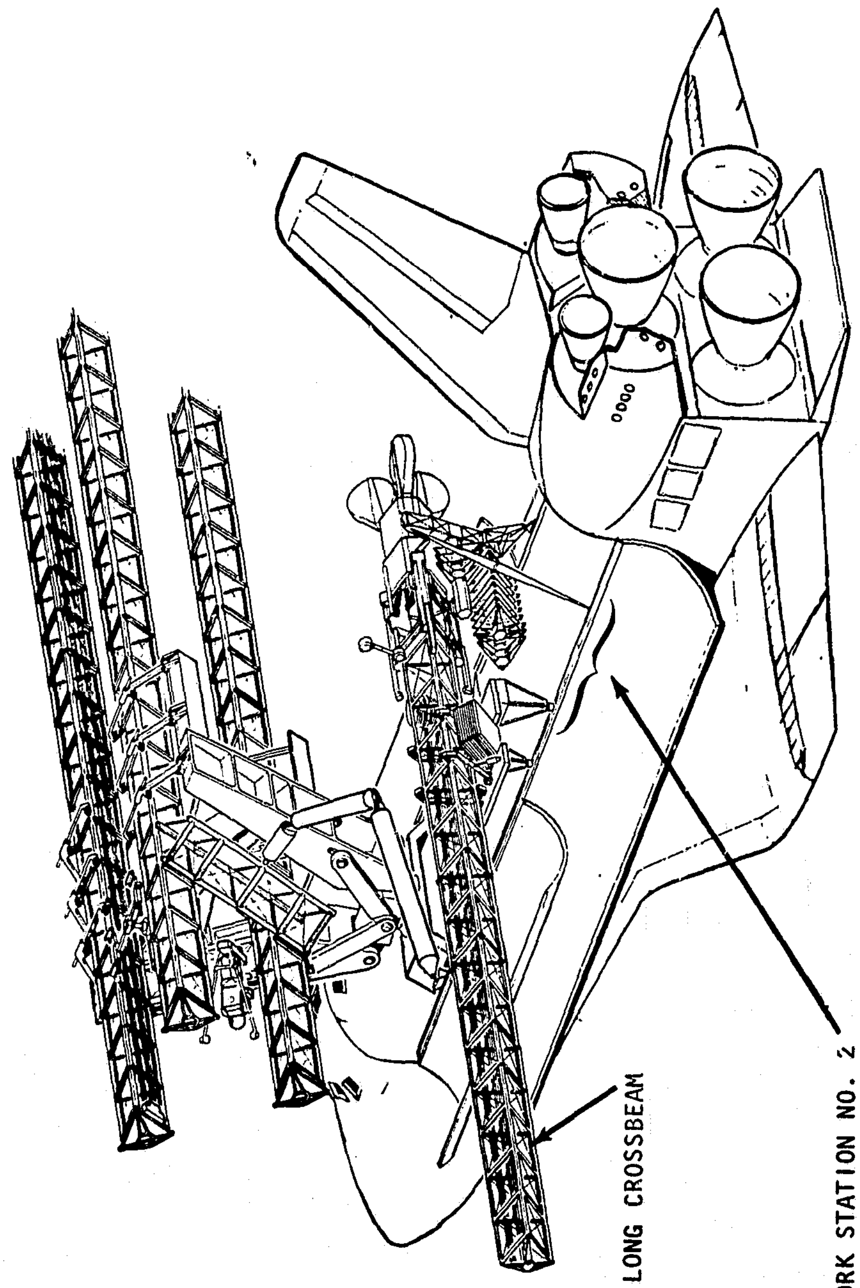
PREPARED BY: ROEBUCK	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.2
DATE: 12/4/79	FABRICATE CROSSBEAM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



FORM 994-B-1 REV 12-78

ACTIVITY 12.3

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

11.1 Join Transverse Beam (No. 1) to Longitudinal Beams → 12.1 Transport Transverse Beam No. 2 → Repeat 11.1 through 11.3 for Transverse Beam (No. 2)

12.2 Fabricate Crossbeam

12.3 Install Attach Ports (to Crossbeam No. 1)

REFERENCE DATA

1. Drawing 42662-52, No. 2 Construction Station
2. Drawing 42662-72, Attach Port
3. Space Construction Data Base
4. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), Part III*, Mid-Term Briefing, CASD-AS78-013, 13 December 1978
5. Construction Activity Data Sheet: *3.2, Install Attachment Ports on Longitudinal Beam No. 1*

DESCRIPTION OF ACTIVITY (see Attachments)

The activity consists of installing an attachment port at each end of the crossbeam during construction at Work Station No. 2 as shown in Reference 2. This activity is identical for both long and short crossbeams. The attach ports for the long crossbeams are designed to mate with payloads; therefore, they are equipped with electrical connections. The connector interface to the crossbeam electrical lines is mechanized for remote actuation. (see Attachment 2). The two types of attach ports are stacked in the sequence required on the attach port magazine.

The function begins with rotating an installation device (loaded with attachment port) into alignment with the beam machine after a short section of beam is fabricated. Then, the legs of the attachment port are inserted into the beam caps, as shown in Reference 2, and welded in place. The weld is load-tested and the port is released; then, the installation device is rotated out of alignment and reloaded with the second attachment port. After the crossbeam is fabricated, cut off, and translated axially away from the beam builder machine, installation of the second port is performed in a manner similar to that for the first—but in opposite direction of motion. The function is complete when the installation device is rotated out of alignment with the beam.

ACTIVITY 12.3

CONSTRUCTION SUPPORT EQUIPMENT

1. No. 2 construction station structural support elements
2. Attach port magazine and installation mechanisms
3. Beam builder
4. TV camera and lights
5. Controls and display systems for operation of installation device for attachment ports

TIMELINE

First Port: 4.12 minutes (interrupts beam fabrication 2.28 minutes)
Second Port (after beam fabrication): 3.86 minutes
Total time for port installation: 7.98 minutes (see Reference 5 for timeline details)

POWER/ENERGY

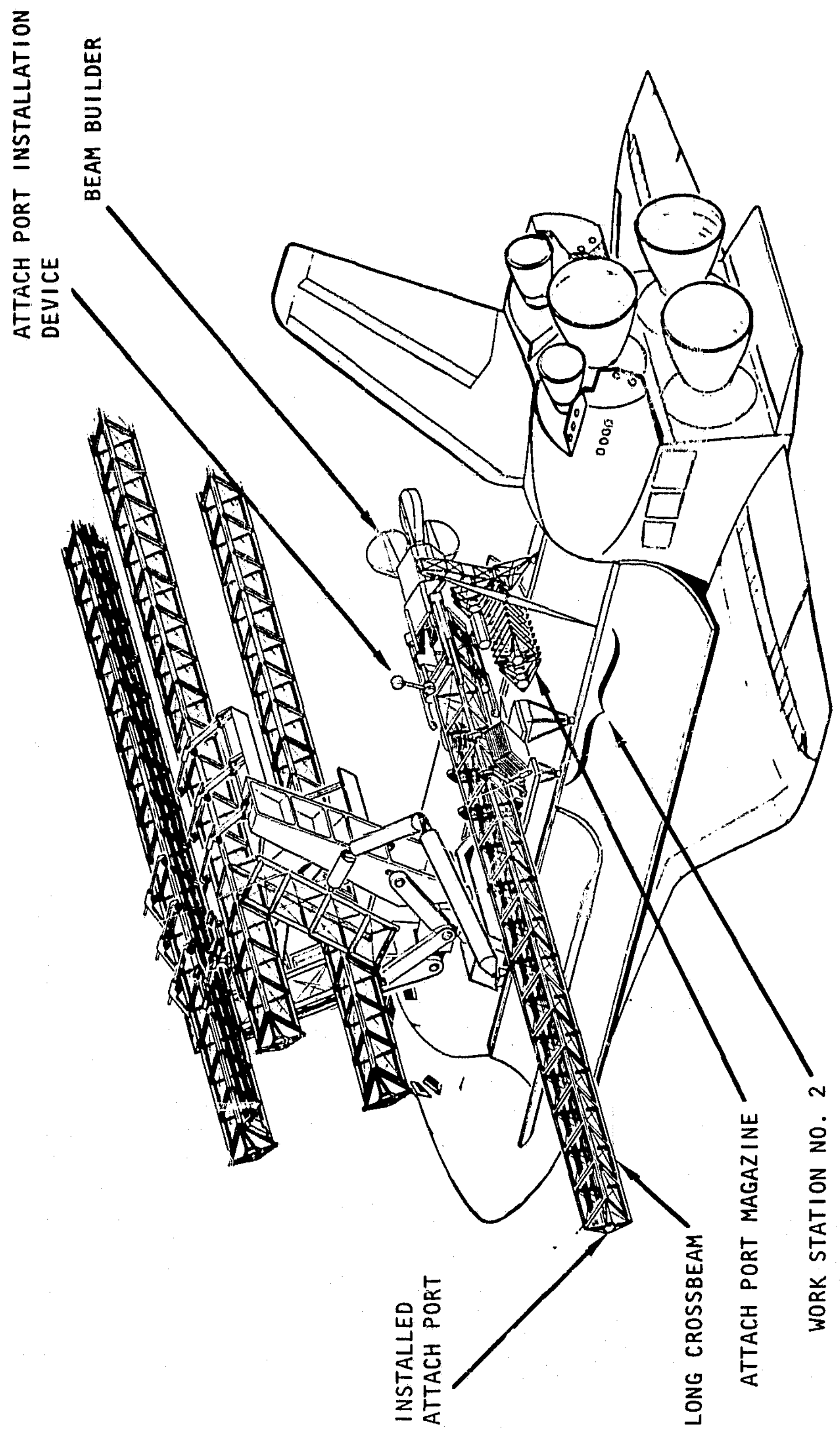
IVA: One person, continuously, during each installation sequence
EVA: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

- Development of space-qualified installation and load testing devices for attachment ports.
- Resistance heating of intermediate filler material for welding of composite materials without active clamping.

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.3
DATE:	INSTALL ATTACH PORTS (TO CROSSBEAM NO. 1)	MODEL NO. ETVP
		DWG. NO.

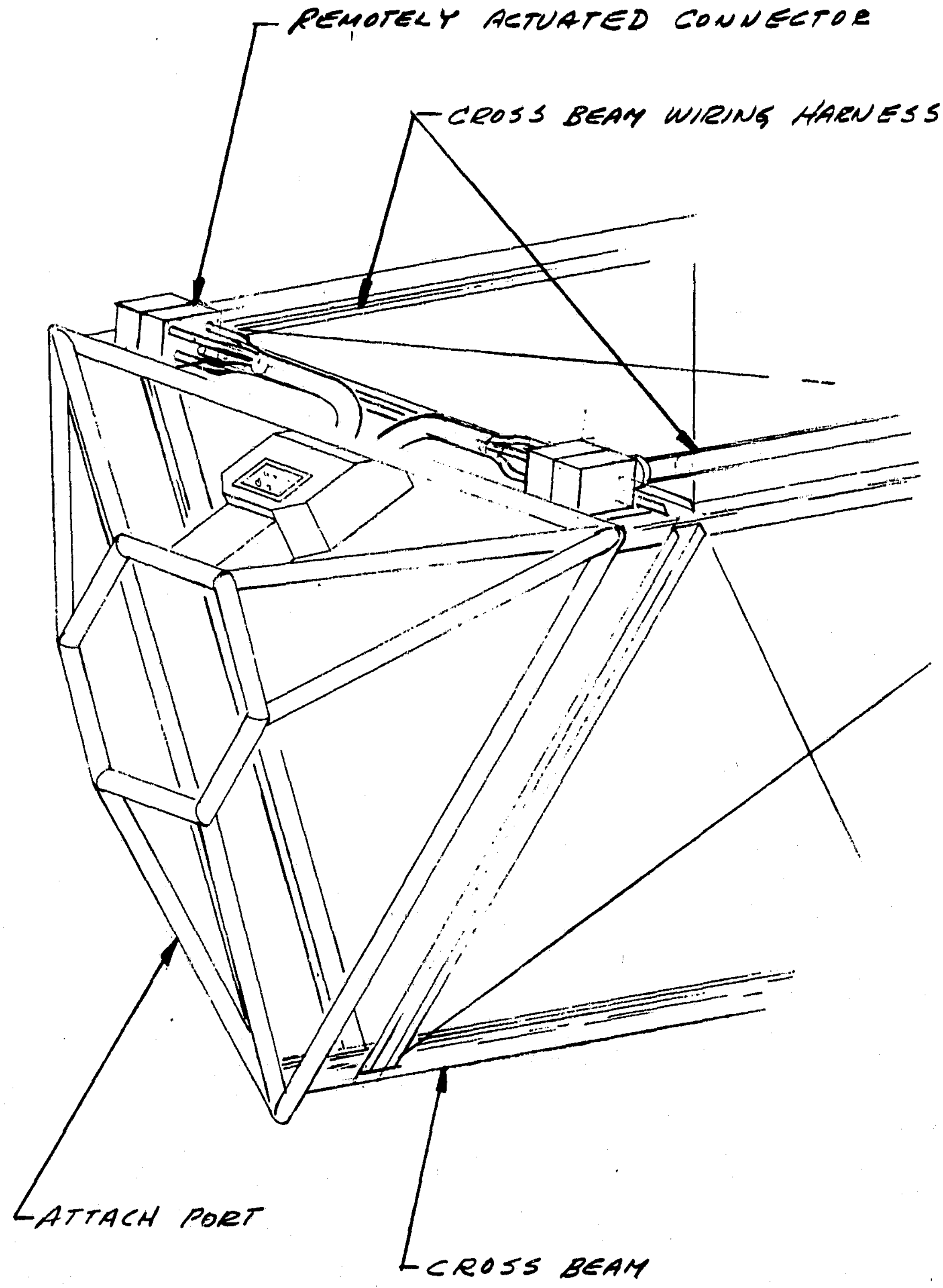
ATTACHMENT 1



FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.3
DATE:	INSTALLATION OF ATTACHMENT PORTS TO CROSS BEAMS	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2



FORM 994-B-1 REV 12-78

ACTIVITY 12.4

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

12.2
Fabricate Crossbeam

12.3 Install Attach Ports (to Crossbeam No. 1)

Repeat 9.2 (Intersection Fittings to Crossbeam No. 1)

12.4 Install Electrical Lines on Crossbeam (No. 1)

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-52, Number 2 Construction Station
3. Drawing 42662-56, Electric Cable-Laying Machine

DESCRIPTION OF ACTIVITY

At No. 2 Construction Station the electrical lines and connectors are automatically installed on the crossbeam as it is fabricated, as described in Attachment 1, and shown on Attachments 3 and 4.

CONSTRUCTION SUPPORT EQUIPMENT

1. Electrical line reel and installation machine
2. Controls and displays for electrical line installation

TIMELINE

Lay electrical lines at 1.08 m/sec (see Attachment 2)

POWER/ENERGY

Average power, 0.012 kW; peak power, 0.02 kW; energy 0.6 kJ (see Attachment 2)

CREW LOAD: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Design and development of electrical cable-laying machine

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.4
DATE:	INSTALL ELECTRICAL LINES CROSSBEAM (NO. 1)	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

ELECTRICAL LINE REEL AND INSTALLATION MACHINE

The general configuration of a machine for dispensing and installing electrical lines and connectors onto the crossbeams is shown in Attachment 3. There are two drums—one for the power lines and one for the data lines. Each drum contains seven assembled cables, i.e., the full complement for the platform. The seven cables are loaded end to end in the continuous bandolier which takes the cables from the drum and presents them to the installation stations. The reason for loading the cables into a bandolier is to overcome the prblems of feeding a discontinuous item such as seven unconnected cables. The bandolier is wound in a helix around the drum, one layer deep. It leaves the drum, passes around a fixed location pulley, and returns to rewind on the drum. The drums must move outward as they rotate to accommodate the passage of the helically wound bandoliers.

Each cable assembly consists of 20 m of line with a connector at each end and clips spaced at intervals to secure the line to the crossmembers of the crossbeam (Reference: Drawing 42662-56).

As the cable assembly on the bandolier moves from the drum toward the fixed location pulley, the front connector is stripped from the bandolier by the end connector installation station. The beam halts and the connector is mated with the unit preinstalled on the front end of the beam.

The beam continues to advance as it is manufactured by the beam builder. Each bay of the beam takes 80 seconds to build—40 seconds moving and 40 seconds stationary, while the crossmembers are welded onto the beam caps. The cable machine is positioned relative to the beam builder so that during the 40-second pause the clip installation station is opposite the crossmember on which a clip is due to be secured. The clips are part of the cable assembly and are secured to the crossmembers by Velcro.

The rear connector is installed by the end connector installation station in the same fashion as the front connector.

FORM 994-B-1 REV 12-78

ACTIVITY 12.4

ATTACHMENT 2

Time, Power, and Energy Estimate for Installing Electrical Lines on Crossbeam No. 1

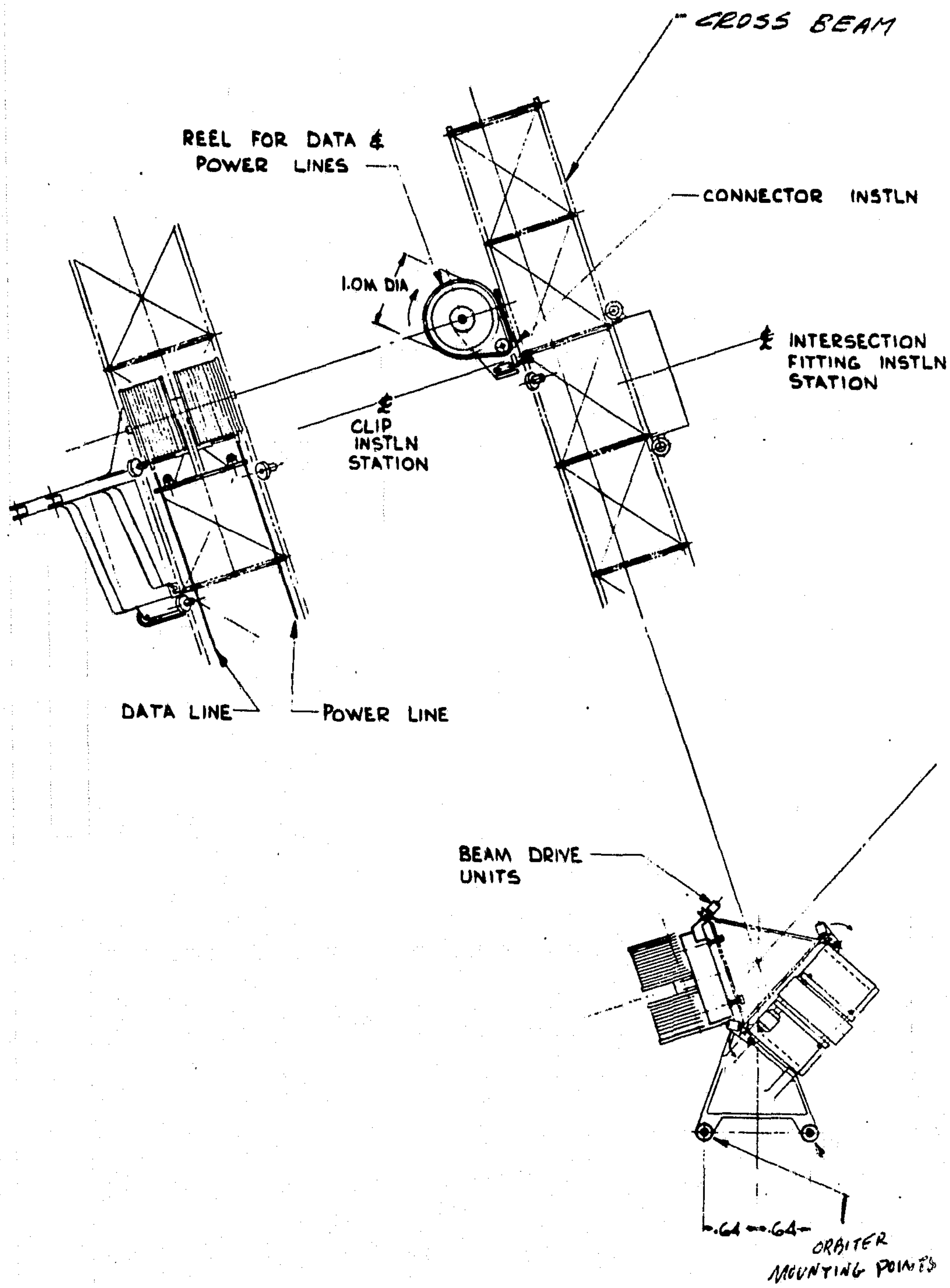
Task	Duration (Secs)	Peak Power (kW)	Avg Power (kW)	Energy (kJ)
1. Build short section of beam				
2. Add end attach port #1				
3. Advance beam				
4. Plug in the connectors at end attach port #1 and retract the arms				
5. Advance and build remainder of beam. Total beam build time = (14x80) + 40 = 1160 seconds Note: Line laying proceeds with beam advance. Line clips and intersection fittings are installed while beam is halted for crossmember joining	5	.02	.02	.1
6. Add end attach port #2				
7. Advance beam to connector installation station	40	.01	.01	.4
8. Plug in the connectors at end attach port #2 and retract the arms	5	.02	.02	.1
Additional Serial Time	50	.02**	.012 *	.6

$$\text{*Average power} = \frac{\text{energy summary}}{\text{total activity time}}$$

**Peak power and summary based upon peak power of individual activities, subjectively estimated, being performed simultaneously.

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.4
DATE:	INSTALL ELECTRICAL LINES ON CROSSBEAM	MODEL NO. ETVP
		DWG. NO.

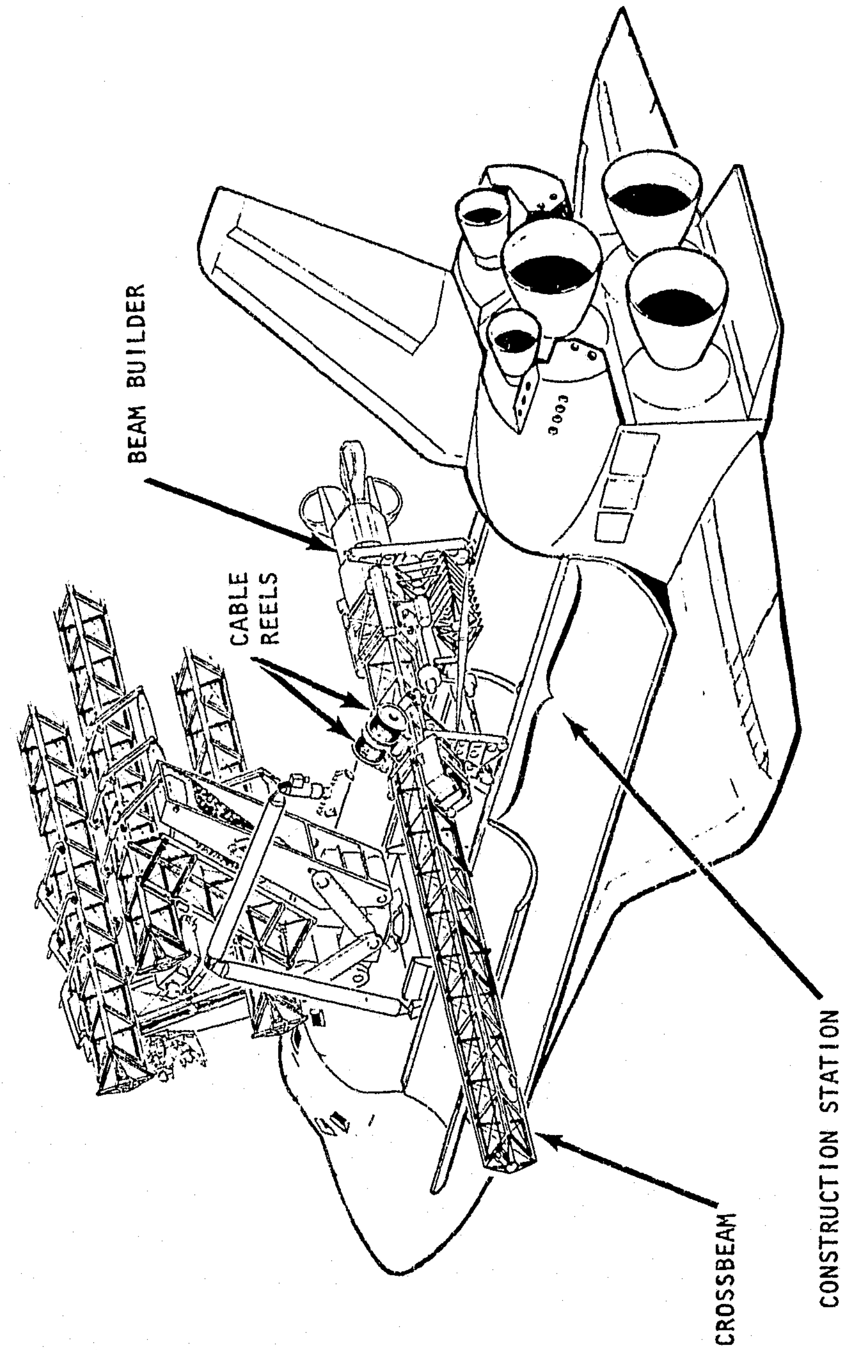
ATTACHMENT 3



FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 12.4
DATE:	INSTALL ELECTRICAL LINES ON CROSSBEAM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 4



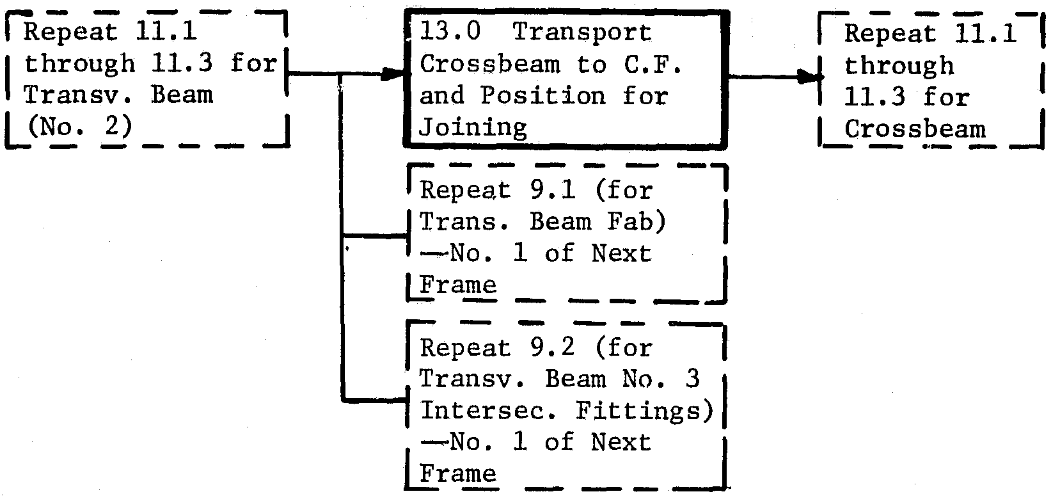
FORM 994-B-1 REV 12-78

ACTIVITY 13.0 PRECEDING PAGE BLANK NOT FILMED

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY



REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-50, Construction Fixture
3. Drawing 42662-55, EVA Work Station
4. Convair Division of General Dynamics, *Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS), Part III*, Mid-Term Briefing, CASD-AS78-013, 13 December 1978 (describes beam-builder machine)
5. *Space Shuttle System Payload Accommodations Level II Program Definition and Requirements*, Volume XIV, JSC 07700, Revision F, August 17, 1979
6. *Performance Specification Manipulator Arm, Shuttle RMS*, SPAR-SG 366, Issue F, May 1978, Corrections through April 1979

DESCRIPTION OF ACTIVITY

The modified RMS grasps and transports a crossbeam from Work Station No. 2 to within "capture range" of the beam positioner at Work Station No. 1, releases the beam, and returns as shown in Attachments 1 through 4. The beam positioner receives the crossbeam for joining to the longitudinal beams. The RMS is under control of the IVA operator. However, during the last five minutes, an EVA astronaut provides verbal/visual feedback.

ACTIVITY 13.0

CONSTRUCTION SUPPORT EQUIPMENT

1. Beam-builder machine (Reference 4)
2. Modified orbiter RMS with upper arm roll joint and special end effector (Reference 5)
3. Tri-beam construction fixture (Reference 2)

TIMELINE

Refer to Attachments 4 and 5. Time required: 33.4 minutes.

POWER/ENERGY

Peak power, 2.25 kW; average power, 1.606 kW; energy, 3218 kJ (see Attachment 5)

CREW LOAD

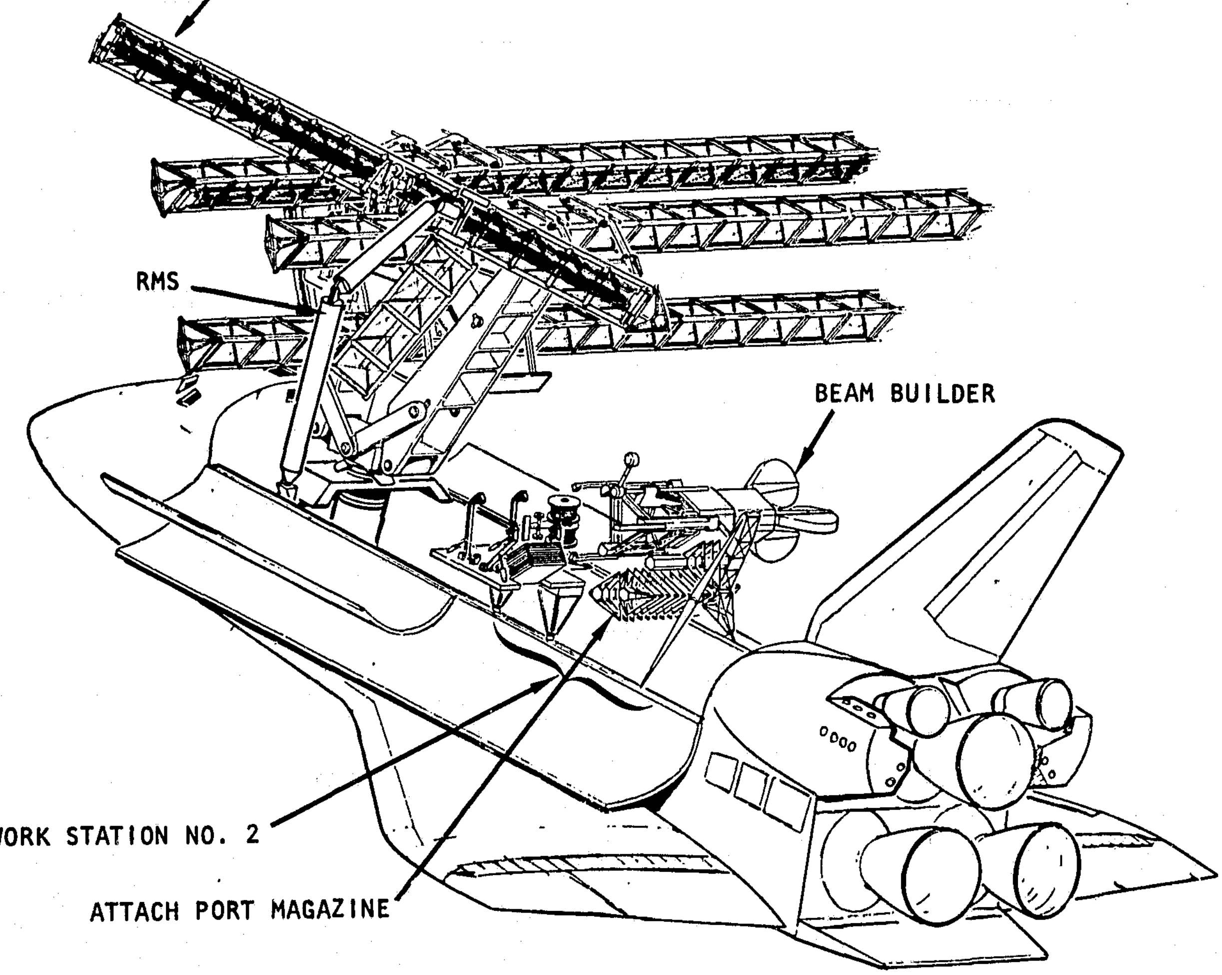
IVA: 1.0 man, 44 minutes
EVA: 1.0 man, 5 minutes

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Roll joint for RMS upper arm (±100 degrees)
2. RMS end effector for grasping transverse beam
3. Beam positioner control and position sensing system

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 13.0
DATE:	TRANSPORT CROSSBEAM TO CONSTRUCTION FIXTURE AND POSITION FOR JOINING	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1



FORM 994-B-1 REV 12-78

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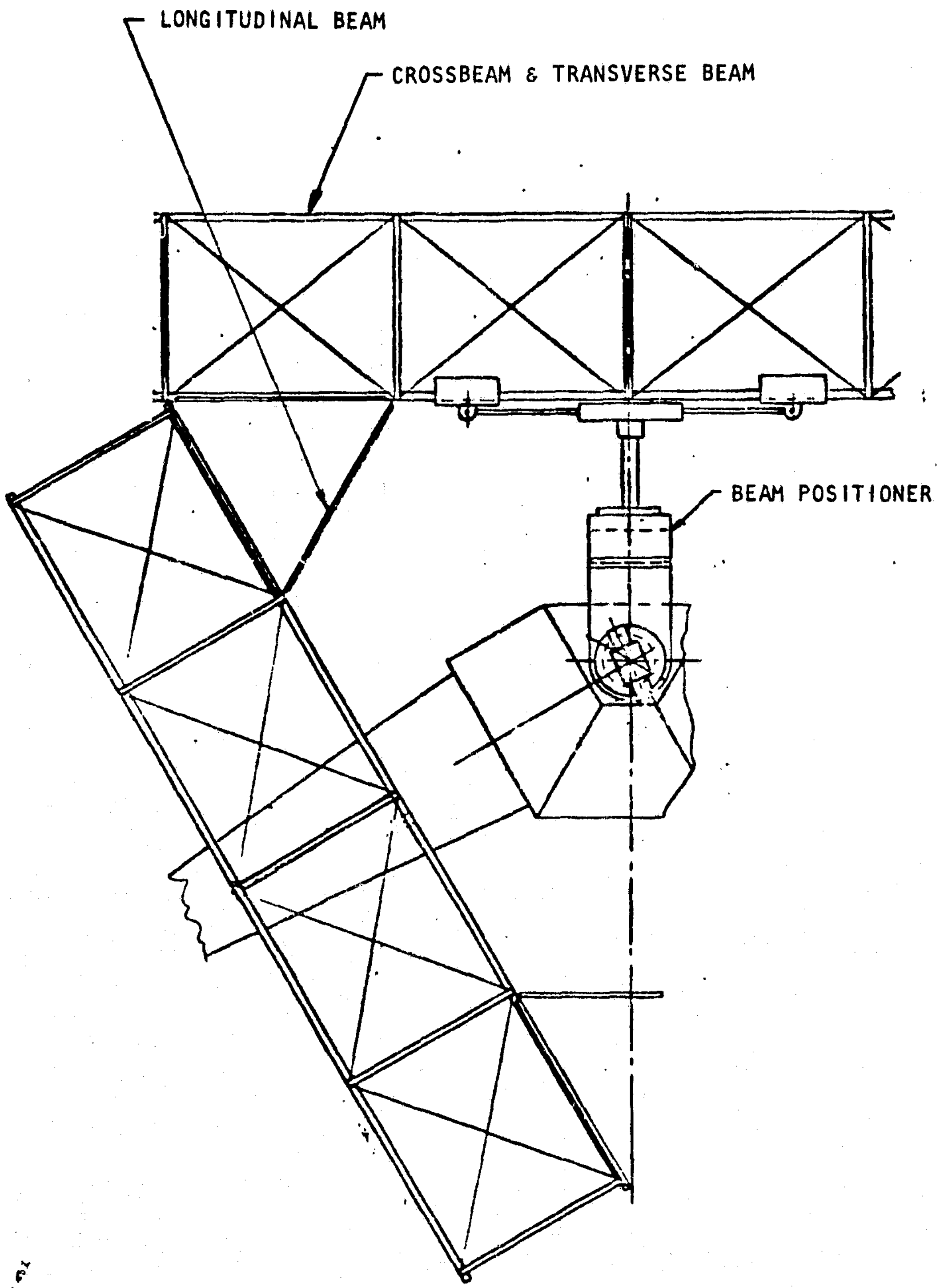
CHECKED BY:		ACTIVITY 13.0
DATE:	TRANSPORT CROSSBEAM TO CONSTRUCTION FIXTURE AND POSITION FOR JOINING	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



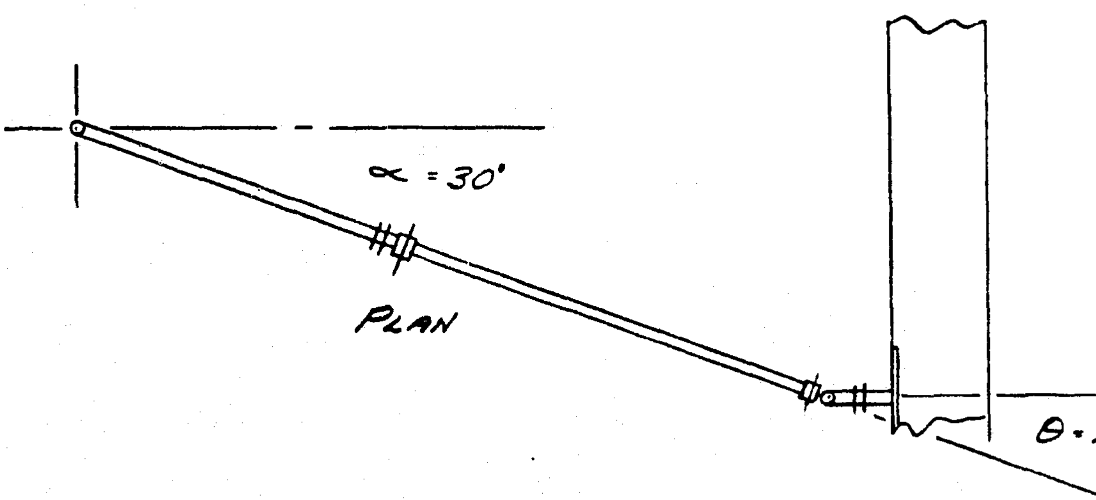
FORM 993-B-1 REV 12-78

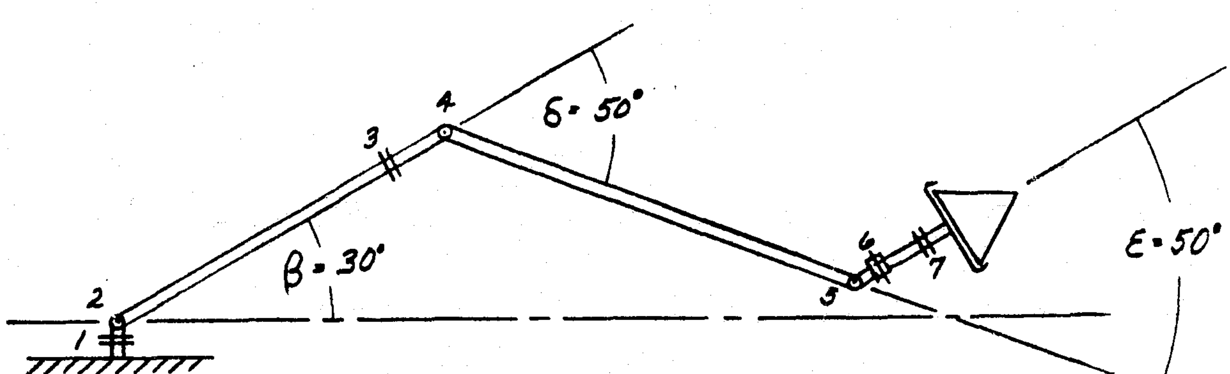
PREPARED BY: C. H. FRITZ	Space Systems Group / Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 13.0
DATE: 11-29-77	TRANSPORT CROSSBEAM TO CONSTRUCTION FIXTURE AND POISITION FOR JOINING	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 3

RMS JOINT INITIAL CONDITIONS

1. SHOULDER YAW
2. SHOULDER PITCH
3. UPPER ARM ROLL
4. ELBOW PITCH
5. WRIST PITCH
6. WRIST YAW
7. WRIST ROLL





FORM 994-B-1 REV 12-76

ATTACHMENT 4

ACTIVITY 13.0

TRANSPORT CROSSBEAM TO CONSTRUCTION FIXTURE AND POSITION FOR JOINING—SINGLE JOINT DRIVE MODE

	JOINT 1	JOINT 2	JOINT 3	JOINT 4	JOINT 5	JOINT 6	JOINT 7
INITIAL SETUP ANGLES →	$\alpha = 45°$ YAW	$\beta = 40°$ PITCH	$\gamma = 0°$ ROLL	$\delta = 50°$ PITCH	$\varepsilon = 80°$ PITCH	$\theta = 0°$ YAW	$\lambda = 0°$ ROLL
TRANSPORT STEPS							
1		10°					
2				50°			
3							180°
4	10°		90°				
5							45°
6					30°		
7						30°	
8		10°					
9	10°			20°			
10					10°		
TOTALS	20°	20°	90°	70°	40°	30°	225°
JOINT RATES (DEGREES/MINUTE) *	13.74	13.74	13.74**	19.26	28.56	28.56	28.56
TIME (MINUTES)	1.46	1.46	6.55	3.63	1.40	1.05	7.88
Σ TIME (MINUTES)	1.46	2.92	9.47	13.10	14.50	15.55	23.43

*REF. 6, p. 3-39; **ASSUMED VALUE FOR ADDITIONAL RMS JOINT

ATTACHMENT 5

ACTIVITY 13.0

TIME AND POWER SUMMARY

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. PWR. (kW)	ENERGY (kJ)
1. MOVE RMS TO POSITION	-	-	-	-
2. GRASP COMPLETED BEAM WITH RMS, RELEASE BEAM FROM BEAM BUILDER	180	0.845 1.050†	0.845 0.525†	152.1 94.5
3. TRANSPORT BEAM WITH RMS FROM BEAM BUILDER TO ASSEMBLY FIXTURE BEAM POSITIONER "ACCEPTANCE" LOCATION	1404	0.845 1.050†	0.845 0.525†	1186.4 737.1
4. GRASP BEAM WITH BEAM POSITONER; RELEASE RMS	120	0.845 1.050† 0.100††	0.845 0.525† 0.100††	101.4 63.0 12.0
5. RETURN RMS TO BEAM BUILDER LOCATION (USE 25% OF ITEM 3)	300	0.845 1.050†	0.845 0.525†	253.5 157.5
SIMULTANEOUS OPERATIONS (NON-ADDITIVE) LIGHTS, TV CAMERAS & HEATERS	(2004)	0.173 0.80	0.173 0.057	346.7 114.2
TOTALS	2004	2.248*	1.606**	3218.4

*PEAK POWER AND SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES SUBJECTIVELY ESTIMATED BEING PERFORMED SIMULTANEOUSLY.

**AVERAGE POWER = $\frac{\text{ENERGY SUMMARY}}{\text{TOTAL ACTIVITY TIME}}$

†HEATER
††BEAM POSITIONER

ACTIVITY 14.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

14.0 Connect electr. lines from Crossbeam to Longitudinal Beam → 15.0 Translate Struct. Assembly One Bay Length

REFERENCE DATA

1. Space Construction Data Base

2. Drwing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-50, Construction Fixture
4. Drawing 42662-55, EVA Work Station

DESCRIPTION OF ACTIVITY (see Attachments 1, 2, and 3)

After the completion of a full bay with a long crossbeam, the electrical interface between the wiring cables on the longitudinal beam and crossbeam is accomplished by an EVA astronaut manually moving wire cable pigtails from stowed positions on the crossbeam and joining the cable connectors to mating connectors located on the longitudinal beam, as shown in Attachment 2.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture (Reference 3)
2. EVA work station (Reference 4)
3. Lighting
4. Self-powered electrical connectors

TIMELINE

14 minutes (see Attachment 5)

POWER/ENERGY (see Attachment 5)

Peak power, 0.5 kW; average power, 0.4 kW; energy, 336 kJ; includes 0.18 kW for lights on cherry picker.

CREW LOAD

One EVA astronaut continuously

DEVELOPMENT TECHNOLOGY REQUIREMENTS

Development of space-qualified, self-powered electrical connectors

ATTACHMENT 1

The activity begins after the completion of one bay with a long crossbeam, and is performed on alternate succeeding bays after both transverse beams and the long crossbeam have been assembled, and all six diagonal cords have been attached to the platform interfaces.

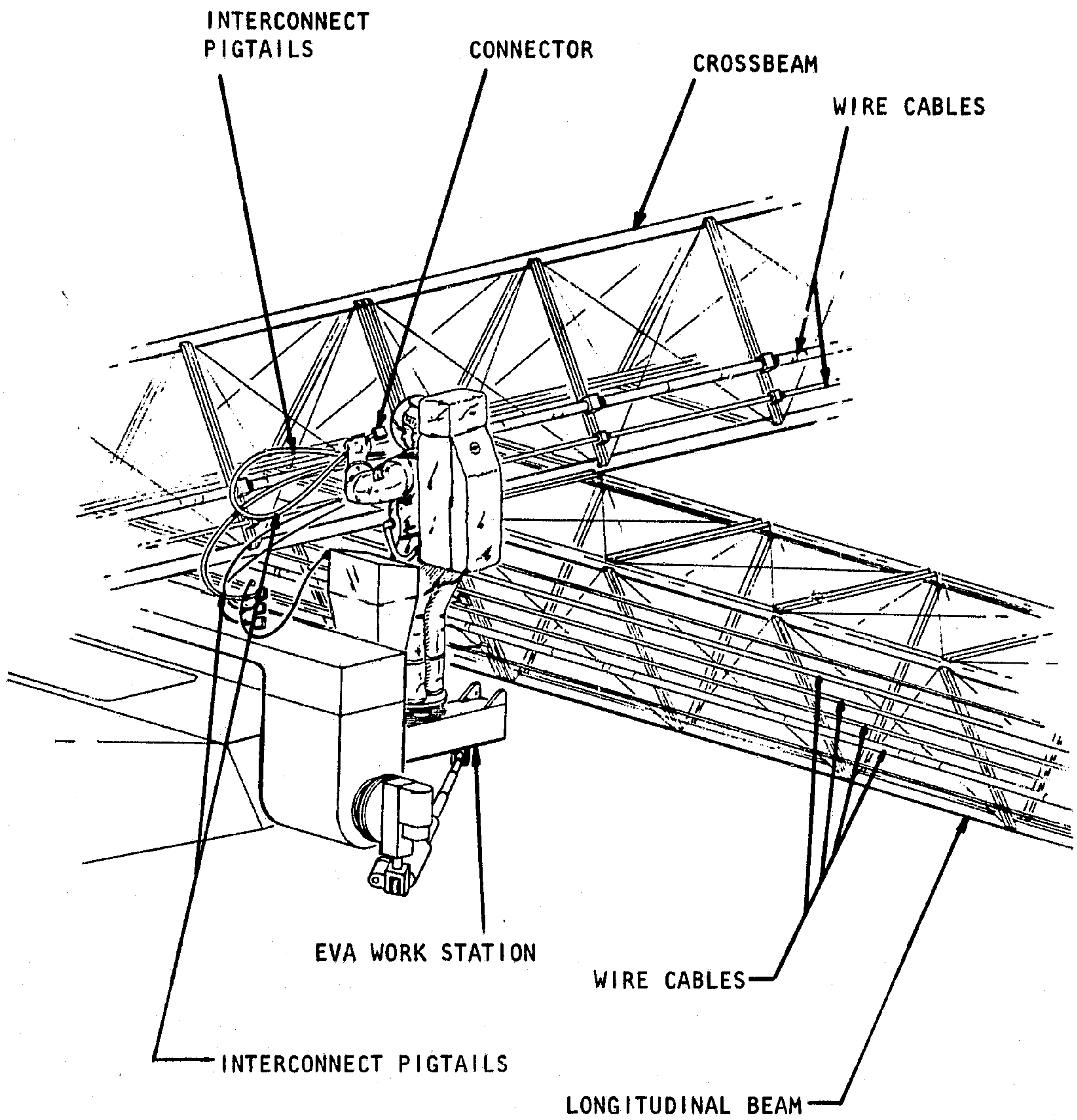
The EVA station is translated to position the astronaut adjacent to the leading surface of the crossbeam in the vicinity of the double crossmember. Here, the astronaut releases the secured ends of the Velcro straps and wraps them around the double crossmember, thus securing the cables at the pigtail breakout location. Next, the astronaut removes the four cable pigtails from their cable-run Velcro attachment and secures them to a holding device on the EVA station (or astronaut's pressure garment), as shown in Attachment 2, page 1.

The EVA station is repositioned so that the astronaut now faces the double crossmember on the inner face of the longitudinal beam. Again, the astronaut releases the attached straps and wraps them around the crossmember, securing the cable at the connector ends. The astronaut removes the secured pigtails one at a time and mates them with the appropriate connector attached to the longitudinal beam, as shown in Attachment 2, page 2. After all the electrical connections have been made, by joining the self-powered connectors (shown in Attachment 4), the astronaut reaches up to the mid-point of the pigtails where he releases a Velcro strap attached to one line. He then wraps the strap tightly around all four pigtails, as shown in Attachment 2, page 3.

The electrical power and data distribution concept is shown in Attachment 3.

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 3
CHECKED BY:		ACTIVITY 14.0
DATE:	CONNECT ELECTRICAL LINES FROM CROSSBEAM CABLES TO LONGITUDINAL CABLES	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2

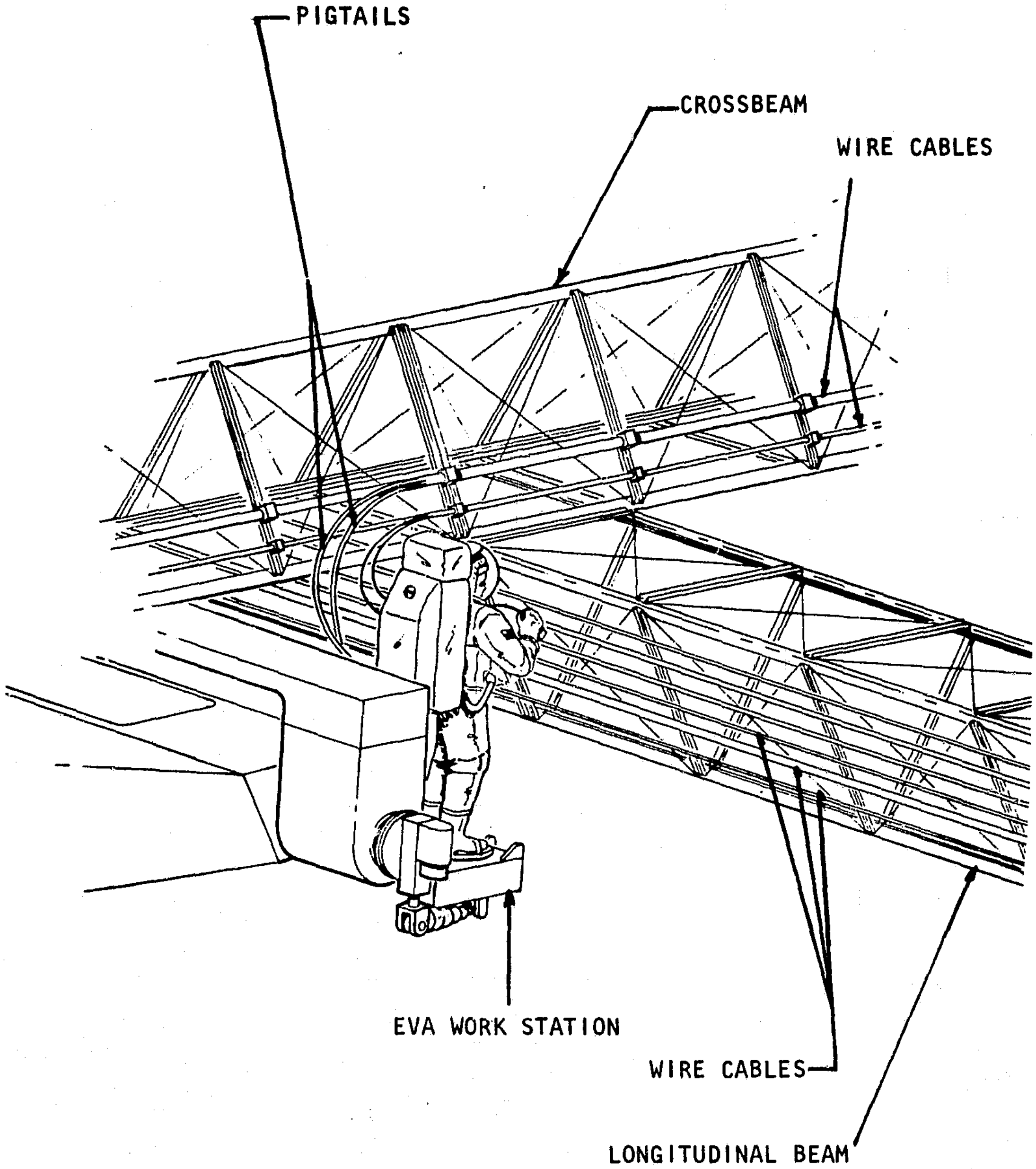


DETACHING CROSSBEAM CABLE PIGTAILS PREPARATORY TO MAKING CONNECTIONS TO LONGITUDINAL BEAM CABLES.

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 2 OF 3
CHECKED BY:		ACTIVITY 14.0
DATE:	CONNECT ELECTRICAL LINES FROM CROSSBEAM CABLES TO LONGITUDINAL CABLES	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2

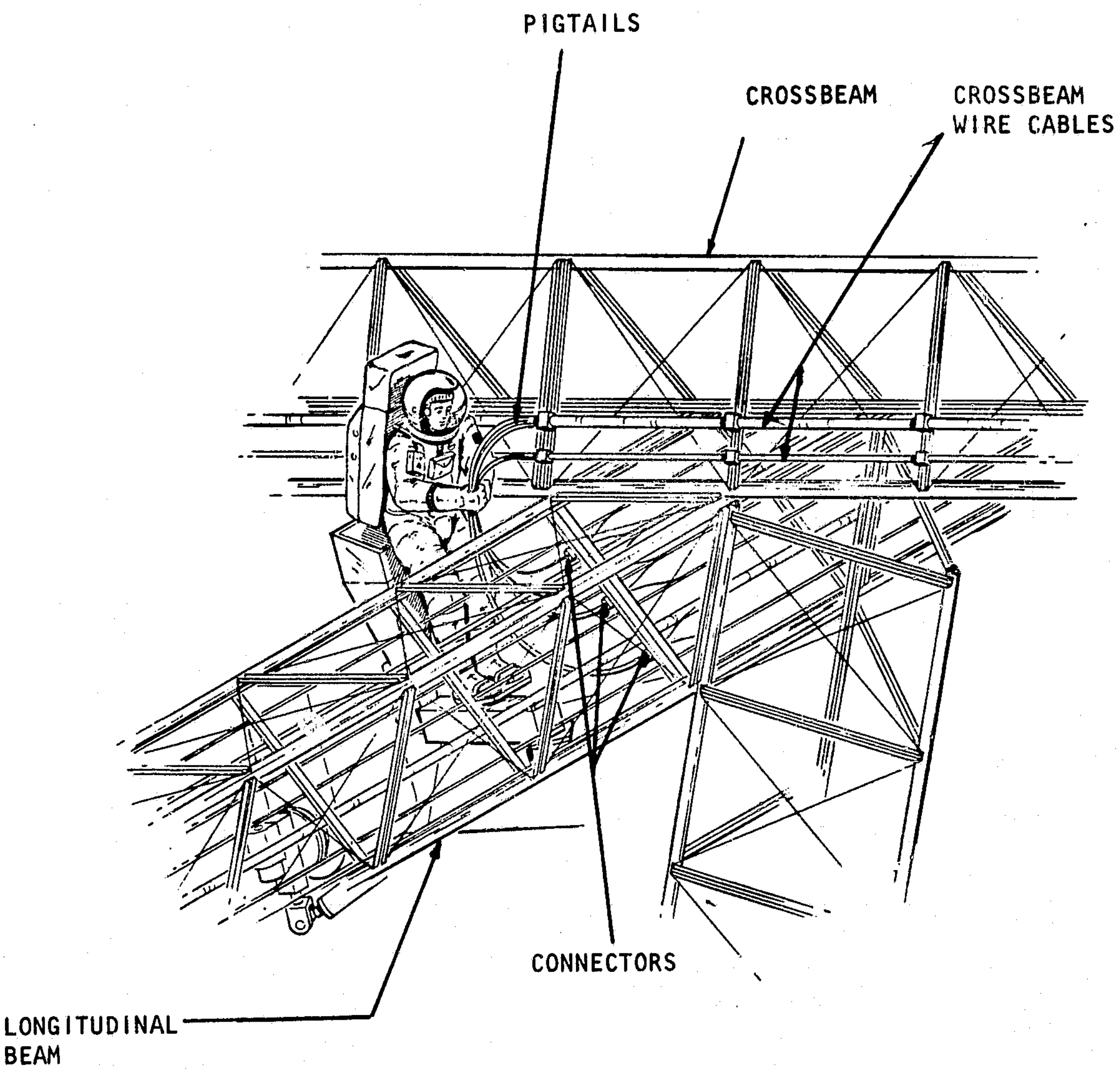


ATTACHING ELECTRICAL CONNECTORS TO LONGITUDINAL BEAM CABLE INTERFACES

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 3 OF 3
CHECKED BY:		ACTIVITY 14.0
DATE:	CONNECT ELECTRICAL LINES FROM CROSSBEAM CABLES TO LONGITUDINAL CABLES	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2



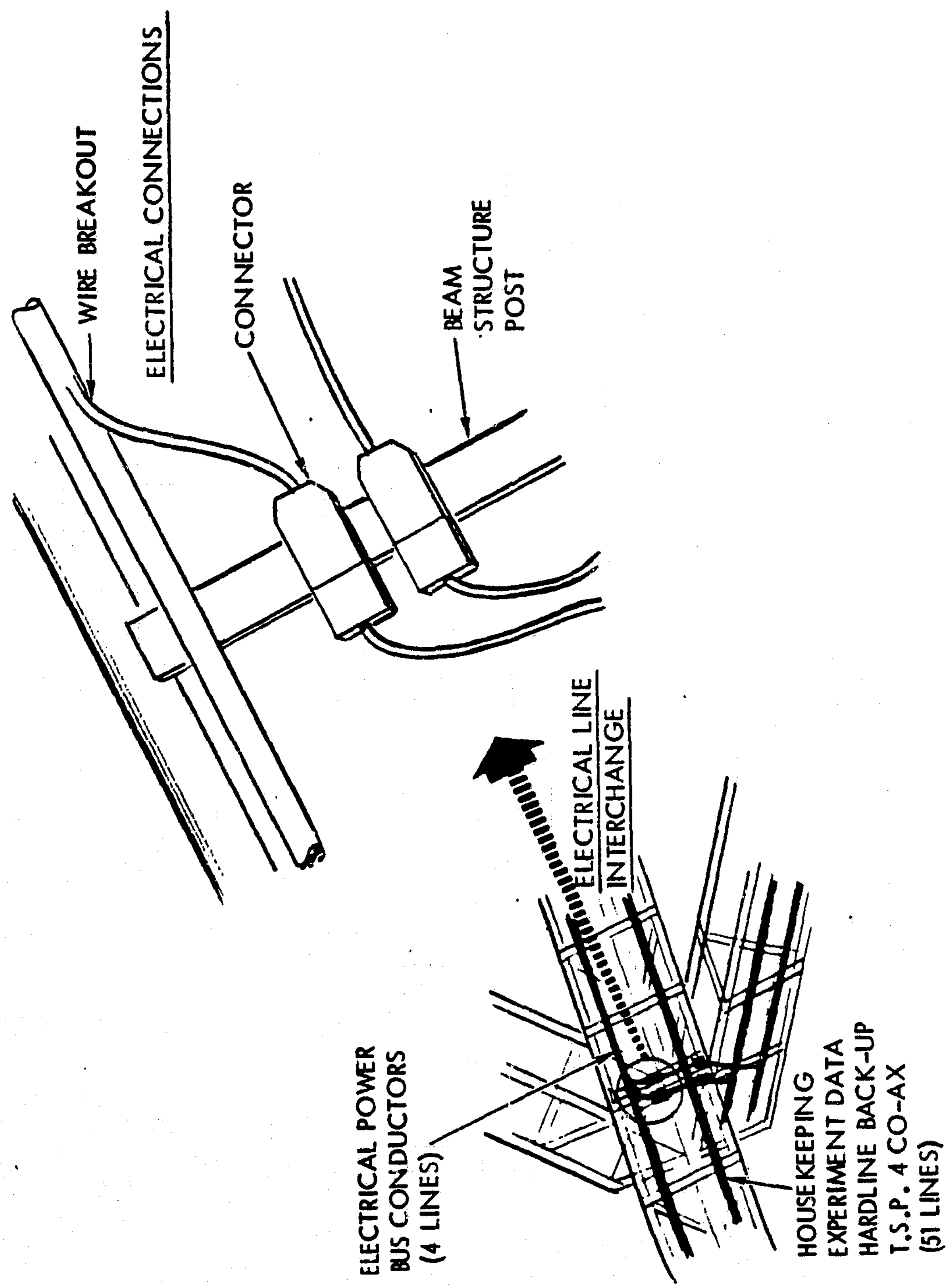
BANDING PIGTAILS WITH VELCRO STRAPS AND SECURING TO LONGITUDINAL BEAM

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 14.0
DATE:	CONNECT ELECTRICAL LINES FROM CROSSBEAM CABLES TO LONGITUDINAL CABLES	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 3

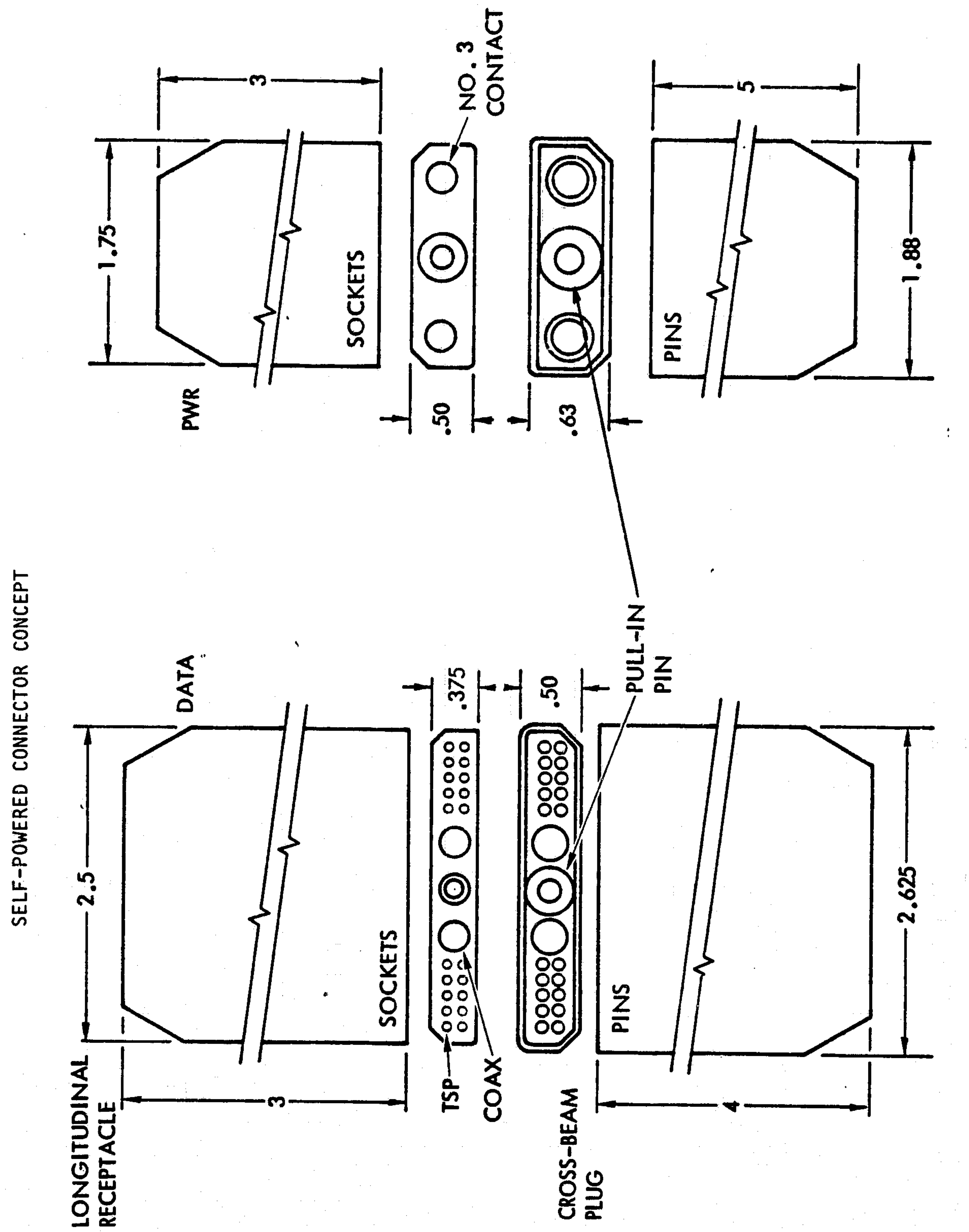
ELECTRICAL POWER AND DATA DISTRIBUTION CONCEPT



FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 14.0
DATE:	CONNECT ELECTRICAL LINES FROM CROSSBEAM CABLES TO LONGITUDINAL CABLES	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 4



FORM 994-B-1 REV 12-78

PREPARED BY:

CHECKED BY:

DATE:

Satellite Systems Division
Space Systems Group

Rockwell International

PAGE NO. 1 OF 1

ACTIVITY 14.0

CONNECT ELECTRICAL LINES FROM CROSSBEAM TO LONGITUDINAL BEAM

MODEL NO. ETVP

DWG. NO.

ATTACHMENT 5

TIME, POWER, AND ENERGY ESTIMATES

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. TRANSLATE EVA WORK STATION TO LONG CROSSBEAM	60	0.5	0.4	
2. RELEASE STRAP TIE AND WRAP AROUND DOUBLE CROSSMEMBER (FOUR PLACES)	120	0.5	0.4	
3. REMOVE FOUR PIGTAILS AND SECURE TO EVA STATION	120	0.5	0.4	
4. REPOSITION EVA STATION	60	0.5	0.4	
5. RELEASE STRAP TIES AND WRAP AROUND DOUBLE CROSSMEMBER	120	0.5	0.4	
6. REMOVE ONE PIGTAIL FROM EVA STATION AND MATE TO APPROPRIATE CONNECTOR ON LONGITUDINAL BEAM (FOUR TIMES)	240	0.5	0.4	
7. TRANSLATE TO MIDPOINT OF PIGTAILS	60	0.5	0.4	
8. RELEASE STRAP AND WRAP PIGTAILS TOGETHER	60	0.5	0.4	
SUMMARY	840 (14 MIN)	0.5	0.4	336

FORM 994-B-1 REV 12-78

ACTIVITY 15.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

14.0 Connect Electrical Lines from Crossbeam to Longitudinal Beam → 15.0 Translate Struct. Assembly One Bay Length → 16.0 Check Struct. Alignment

REFERENCE DATA

1. Drawing 42662-50, Construction Fixture
2. Space Construction Data Base
3. Drawing 42662-45, Tri-Beam Platform Configuration

DESCRIPTION OF ACTIVITY

The entire platform structural assembly, as completed prior to this activity, is translated 12.9 meters with respect to the construction fixture by means of power-driven rollers which grip and position the platform. This action also pays out six cords for cross-bracing the structure.

CONSTRUCTION SUPPORT EQUIPMENT

Tribeam construction fixture—particularly supporting rollers and associated drive motors, controls, and sensors.

TIMELINE

2.16 meters/minute, 60 minutes for 12.9 meters

POWER/ENERGY

Construction fixture: varies only slightly according to mass of structure assembled. Average and peak power estimated at 0.12 kW; energy, 41 kJ (see Attachment 1)

CREW LOAD

IVA: Approximately 0.5 man continuously monitoring
EVA: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Development of construction fixture drive rollers, controls, and sensing system

PREPARED BY: R. Hart	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 15.0
DATE: 12/5/79	TRANSLATE STRUCT. ASSEMBLY ONE BAY LENGTH	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

ENERGY AND POWER CALCULATION

Total weight of moving mass

3 longitudinals	3×266	=	798 lb
6 end caps	6×15	=	90
Wire, 2520 kg×2.2×70%		=	3880
			4768 lb
Weight of crossbeams and transverse beams		=	252 lb
			5020 lb

∴ Initial weight = 4768 lb; final weight = 5020 lb

Velocity = 2.16 m/min = $2.16 \times \frac{3.28}{60}$ = 0.118 ft/sec

Assume average weight of 4894 lb (difference is negligible)

$$\text{Power} = \frac{0.2}{103} \times \text{weight} \times \text{velocity} = \frac{0.2}{103} \times 4894 \times 118 = 0.115 \text{ kW}$$

$$\text{Time to move one bay (12.9 m)} = \frac{12.9 \text{ m} \times 60}{2.16 \text{ m/min.}} = 358 \text{ seconds}$$

Energy = 0.115×358 = 41.17 kJ

SUMMARY

Peak power	0.115 kW
Average power	0.115 kW
Time	358 seconds per bay
Energy	41.17 kJ per bay

FORM 994-B-1 REV 12-78

ACTIVITY 16.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

15.0 Translate Struct. Assembly One Bay Length	→	16.0 Check Structural Alignment	→	Repeat 10.0 through 16.0 (for short crossbeam—except omit 12.5 and 14.0)

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, Engineering and Technology Verification Platform
2. Space Construction Data Base
3. Drawing 42662-50, Construction Fixture

DESCRIPTION OF ACTIVITY (see Attachment 1)

It is essential to monitor and check the geometric configuration of the tri-beam basic structure during its construction. Such checking will indicate deviations such as longitudinal warping, bending, or twisting from the theoretical geometry that may occur. The EVA astronaut will install an electro-optical device on the construction fixture in a position to sight along the platform longitudinal centerline. Targets will be incorporated into the platform structure in the plane of the bay as formed by the transverse and crossbeams. Real-time visual assessment and taking of status pictures will be accomplished via TV in the orbiter crew compartment.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture
2. Lighting
3. Platform alignment target and TV/optical alignment sighting sy

TIMELINE

Viewing and recording of target pattern: 3 minutes per longitudinal bay

POWER/ENERGY: Negligible

CREW LOAD: IVA = 0.2 man, monitoring; EVA = none

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Platform optical alignment checking system
2. Alignment targets and illumination system

ATTACHMENT 1

Platform Structural Alignment

Final platform structural alignment will be the net result of a great many interacting factors including:

- Consistency of heating and forming components
- Welding and joining of components
- Installation and tensioning of X-brace cords
- Drive forces of translation rollers in the construction fixture

The basic structural form of this platform is a triangular tube 136 m long. An effective way to evaluate structural alignment of such a structure is to view the inside of the three longitudinal members from one end along the longitudinal axis. The sets of transverse beams and crossbeams form natural cross-section stations that can individually be visually checked, indicate displacement of a particular station from the theoretical position, and can collectively show twisting or bending trends.

To facilitate visual observation of the displacements from nominal, targets will be incorporated into the intersection fittings that join the transverse beams and crossbeams to the longitudinal beams.

A view down the inside of the platform structure will appear somewhat like the graphic representation of Attachment 2. At any cross-section station there could be six targets appearing in an irregular hexagon. The perspective effect will make the six rows of targets appear to radiate outward from a theoretical vanishing point at the center of the longitudinal axis. In the nominal condition, in which there is perfect platform alignment, the six rows of targets will each appear to be straight and the target spacing will geometrically increase from the longitudinal axis outward. The outermost cross-section station is the one nearest the view point. Any twisting trend in the platform structure will cause the radiating pattern of targets to have a curved appearance. Displacement of a single cross-section station would cause an apparent "dog leg" or local bend in the radiating pattern targets. Fine lines scribed onto a target within the optics can provide comparisons to nominal case and also show permissible variations.

The sighting aperture is best located at some point on the longitudinal axis, which is also the main rotation axis for the beam positioner and astronaut cherry picker. The most advantageous point to place the viewing device is at the end of the rotation support structure upon which these mechanisms are mounted. This arrangement is shown in Attachment 3.

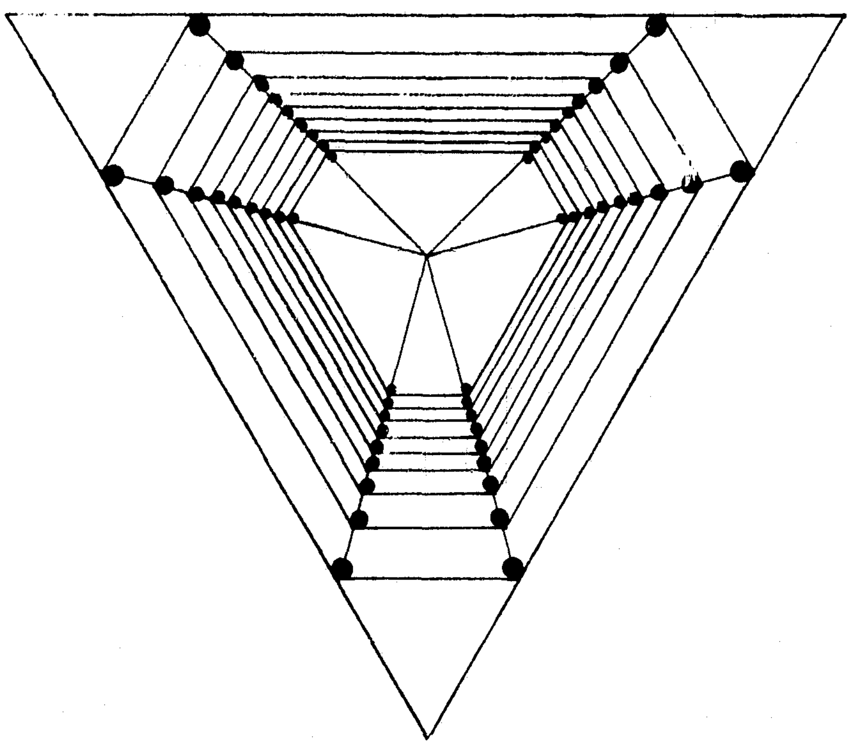
The recommended viewing devices is an electro-optical system that is controlled by the IVA operator and presents a visual display inside the orbiter, possibly on a closed-circuit TV screen. A significant advantage to this type of system is that a permanent record (a photo) can be made of the successive viewings down the line of targets. In case of a contingency, a situation in which the misalignment of the platform structure has reached the point that it might no longer be within acceptable tolerance limits, the TV picture could be transmitted back to earth for evaluation and analysis.

ATTACH. 2 (Cont.)

The primary concern of this measurement activity is to establish that structural alignment of the platform from one end to the other will be satisfactory to prevent overstressing and failure as a column when thrust loads are applied to transfer the platform to geosynchronous orbit.

PREPARED BY: C. Fritz	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		Activity 16.0
DATE: 12-5-79	CHECK STRUCTURAL ALIGNMENT	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

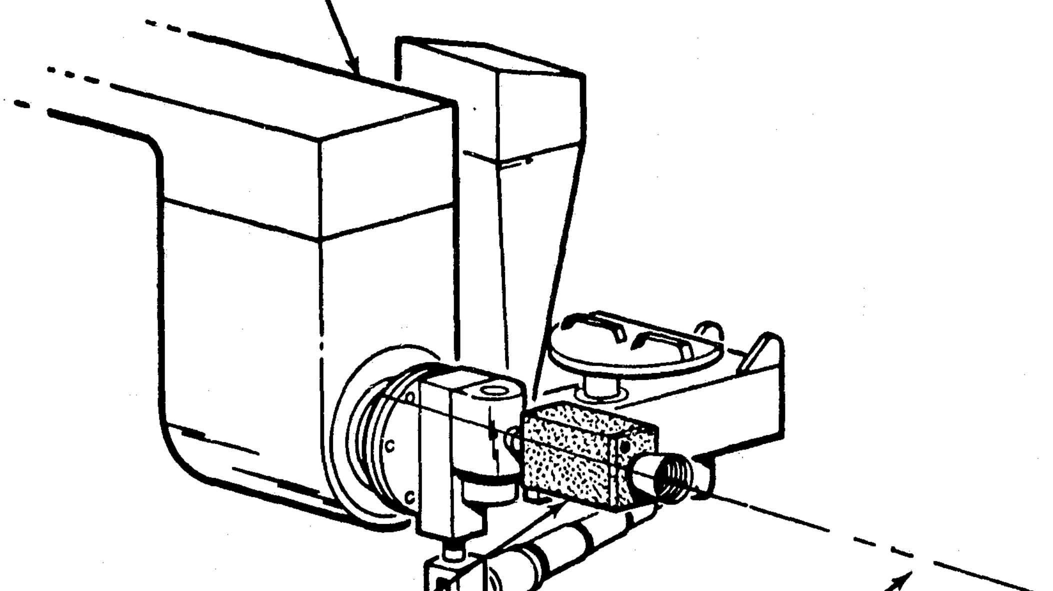


PATTERN OF MARKERS ON INTERSECTION FITTINGS AS VIEWED ALONG CENTERLINE OF TRI-BEAM PLATFORM.

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		Activity 16.0
DATE:	CHECK STRUCTURAL ALIGNMENT	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



FORM 994-B-1 REV 12-78

ACTIVITY 17.1

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CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

Repeat 10.0 through 16.0 (for short crossbeam—except omit 12.5 and 14.0)

17.1 Configure Construction Fixture for Untended Operations

17.2 Stow Return Cargo in Payload Bay

REFERENCE DATA

1. Drawing 42662-50, Construction Fixture
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY (see Attachments 1 and 3)

This activity primarily includes those operations necessary for the deployment and pre-separation checkout of the libration damping system. It will take place at completion of platform assembly, in parallel with the stowage of return cargo in the payload bay, and will be followed by the orbiter separation operations. Included is a short translation of the ETVP to clear the libration damping RCS pods from the end crossbeam.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture (Reference 1)
2. Lighting and TV system

TIMELINE (see Attachment 2)

Estimated 4 minutes for boom deployment, and 22.0 minutes for pre-separation electronic checkout. and 4 minutes for translation of the structure.

POWER/ENERGY

Peak power, 1.9 kW; average power, 0.6 kW; energy, 1100 kJ
(see Attachment 2 for details)

CREW LOAD

IVA = 2.0 men continuously
EVA = None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Tri-beam construction fixture libration damping system

ATTACHMENT 1

LIBRATION DAMPING SYSTEM CONFIGURATION

The libration damping system will consist of: two cold gas RCS modules with 1/2-lb thrusters, each mounted on a foldable boom attached to the construction fixture; a battery module; a computer module, a TT&C module, a cryo sensor module; and two omni antennas. The entire system will be packaged and transported as a part of the main construction fixture. Sheet 3 of Drawing 42662-50, as revised, shows the general arrangement and indicates how the booms will unfold into operating position (as shown on Attachment 3). Power for boom deployment will be furnished by the orbiter.

PREPARED BY: ROEBUCK	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 17.1
DATE: 12/7/79	RECONFIGURE CONSTRUCTION FIXTURE FOR UNTENDED OPERATIONS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

DURATION, POWER, AND ENERGY ESTIMATES

ITEM	OPERATION	DURATION (min)	PK PWR (kW)	AVG PWR (kW)	ENERGY (kJ)
RCS PODS	DEPLOYMENT (TWO SIDES)	4	0.1	0.1	24
LIGHTING	ILLUM. POD DEPLOYMENT	4	0.6	0.6	144
CONS. FIXT.	TRANSLATE ETVP	4	0.1	0.1	24
RMS ARM	VIEWING SYSTEM PLATFORM	10	1.9	1.4	840
TV	OBSERVATION	30	0.07	0.05	90
SUMMARY		30	1.9**	0.6*	1098

$$\text{*AVERAGE POWER} = \frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$$

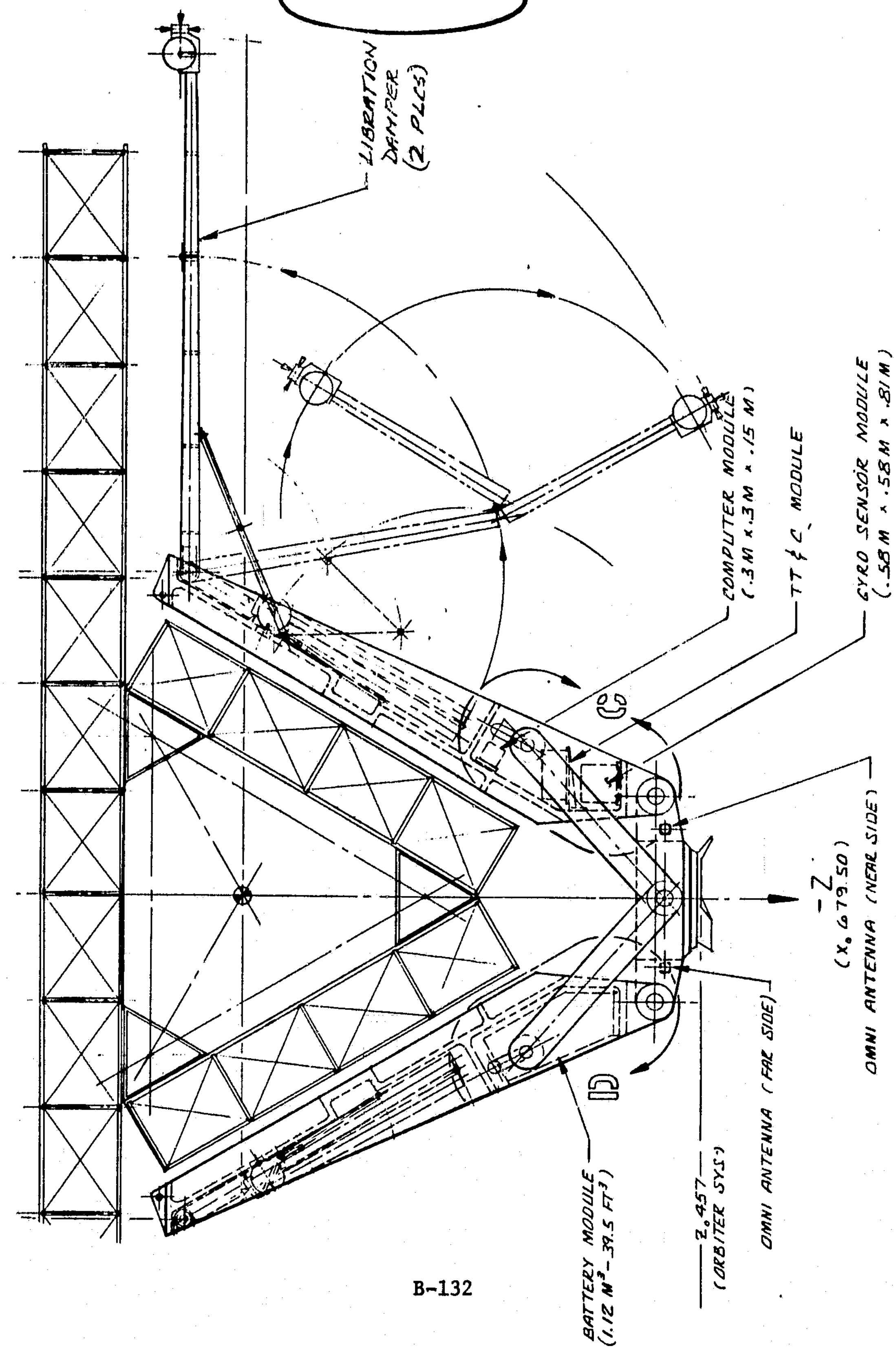
**PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES SUBSEQUENTLY ESTIMATED BEING PERFORMED SIMULTANEOUSLY.

Note: Control/Display power neglected.

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 17.1
DATE	CONFIGURE CONSTRUCTION FIXTURE FOR UNTENDED OPERATIONS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



FORM 994-B-1 REV 12-76

ACTIVITY 17.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY EVALUATION PLATFORM (ETVP)

ACTIVITY

Repeat 10.0 through 16.0 for Short Crossbeams → 17.1 Configure Construction Fixture for Untended Operations

→ 17.2 Stow Return Cargo in Payload Bay

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-50, Construction Fixture
3. Drawing 42662-52, Construction Station No. 2
4. Drawing 42662-53, Orbiter Stowage, First Flight

DESCRIPTION OF ACTIVITY

The activity begins with the removal of equipment from Construction Fixture No. 1 and from Construction Station No. 2, and continues through the stowing of the equipment in the orbiter bay. *Note: Support tripod was stowed in Activity 8.1.* (see Attachments 1, 2, and 3)

CONSTRUCTION SUPPORT EQUIPMENT

RMS with TV and lights

POWER/ENERGY

Peak power, 2.4 kW; average power, 1.6 kW; energy, 10,040 kJ (see Attachment 1)

CREW LOAD

One man continuously, operating RMS 106.5 minutes

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ATTACHMENT 1

Time, Power, and Energy Estimation for Stowing Return Cargo, Activity No. 17.2

SHEET 1 OF 3

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. EVA ASTRONAUT EGRESSES TO THE CONSTRUCTION FIXTURE, TRANSPORTS HIMSELF BY MMU TO CONSTRUCTION STATION NO. 2, RELEASES BRACING STRUT BETWEEN Y-FRAME AND REEL ASSEMBLY FRAMES AND STOWS IT IN PAYLOAD BAY ON EXISTING SUPPORT CRADLE (IN PARALLEL TIME FRAME WITH STEP 2).	(300)	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
2. WITH THE RMS, GRASP THE BEAM BUILDER AT CONSTRUCTION STATION NO. 2	300	0.845 1.050	0.845 0.525	253.5 151.5
3. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE MECHANICAL LATCHES AND ELECTRICAL INTERFACE BETWEEN THE BEAM BUILDER AND THE Y-FRAME	30	0.02	0.02	0.6
4. USING THE RMS, REMOVE THE BEAM BUILDER, ROTATE IT THROUGH 180° AND REPLACE IT ON THE Y-FRAME	1200	0.845 1.050	0.845 0.525	1014. 630.
5. BY REMOTE CONTROL FROM THE CREW CABIN, SECURE THE MECHANICAL LATCHES BETWEEN THE BEAM BUILDER AND Y-FRAME	30	0.02	0.02	0.6
6. RELEASE THE RMS, MOVE THE RMS TO THE CABLE REEL ASSEMBLY AT CONSTRUCTION STATION NO. 2 AND GRASP IT (a)	300	0.845 1.050	0.845 0.525	253.5 157.5
7. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE LATCH POSITIONING THE CABLE REEL, FOLD THE CABLE REEL, AND RELATCH THE CABLE REEL (AS SHOWN IN ATTACHMENT 2). *Note: Can be done parallel in time with Step 2.*	30 30 30	0.02 0.02 0.02	0.02 0.02 0.02	0.6 0.6 0.6
8. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE MECH. LATCHES & ELEC. INTERFACE BETWEEN THE CABLE REEL ASSY AND ITS SUPPORTS.	30	0.02	0.02	0.6

ATTACHMENT 1

Time, Power, and Energy Estimation for Stowing Return Cargo, Activity No. 17.2

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
9. USING ONE RMS, MOVE THE CABLE REEL ASSY TO ITS STOWED LOCATION IN THE ORBITER BAY	1200	0.845	0.845	1014
10. BY REMOTE CONTROL FROM THE CREW CABIN, SECURE THE PAYLOAD RETENTION LATCHES	30	0.02	0.02	0.06
11. RELEASE THE RMS; MOVE THE RMS TO THE Y-FRAME AT CONSTR. STATION NO. 2 AND GRASP IT.	300	0.845 1.050	0.845 0.525	253.5 157.5
12. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE MECHANICAL LATCHES AND ELECTRICAL INTERFACE BETWEEN THE Y-FRAME AND ITS SUPPORT ON THE ORBITER LONGERONS.	30	0.02	0.02	0.6
13. USING THE RMS, MOVE THE Y-FRAME (WITH BEAM BUILDER ATTACHED) TO ITS STOWED LOCATION IN THE ORBITER BAY.	1200	0.845 1.050	0.845 0.525	1014. 630.
14. BY REMOTE CONTROL FROM THE CREW CABIN, SECURE THE PAYLOAD RETENTION LATCHES.	30	0.02	0.02	0.6
15. RELEASE THE RMS; MOVE THE RMS TO THE BRIDGE STRUCTURE ON CONSTRUCTION FIXTURE AND GRASP IT.	300	0.845 1.050	0.845 0.525	253.5 157.5
16. BY REMOTE CONTROL FROM THE CREW CABIN, RETRACT, STOW AND LATCH THE EVA WORK STATION ASSEMBLY TO THE BEAM POSITIONER. FUNCTION PERFORMED IN PARALLEL TIME TO 15.	(300)	0.22	0.1	30
17. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE MECHANICAL LATCHES WHICH FASTEN THE LEGS OF THE BRIDGE STRUCTURE TO THE MAIN YOKE FRAME OF THE CONSTRUCTION FIXTURE. THE ELECTRICAL CONNECTOR IS DISCONNECTED AS THE LATCHES ARE RELEASED. STORED ENERGY DEVICES POWER THE RETRACTION OF THE SUPPORT LEG ASSEMBLIES & THE 90° ROTATION OF THE LEG ASSYS RELATIVE TO THE BRIDGE BEAM ASSY, AS SHOWN IN ATTACH. 3.	30	0.02	0.02	0.6

ATTACHMENT 1

Time, Power, and Energy Estimation for Stowing Return Cargo, Activity No. 17.2

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
18. USING THE RMS, MOVE THE BRIDGE STRUCTURE TO ITS STOWED POSITION IN THE ORBITER BAY ON EXISTING SUPPORT CRADLE.	1200	0.845 1.050	0.845 0.525	1014. 630.
19. BY REMOTE CONTROL FROM THE CREW CABIN, SECURE THE PAYLOAD RETENTION LATCHES.	30	0.02	0.02	0.6
20. RELEASE THE RMS & MOVE IT AWAY FROM THE BRIDGE STRUCTURE.	50	0.845 1.050	0.845 0.525	50.7 31.5
21. TV, 34 W + 23 W AVERAGE HEATING (46 W PEAK); LIGHTS, 173 W; REQUIRED THROUGH STEPS 1 THROUGH 20.	(6390)	0.253	0.230	1469.7
22. STANDBY POWER FOR RMS HEATER DURING NON-TRANSPORT PERIODS (b)	(390)	1.050	0.525	204.8
SUMMARY	6390 (106.5 min) (1.775 hr)	(d) 2.388	(c) 1.57	10,040.3

NOTES

(a) DEVICE FOR INSTALLING INTERSECTION FITTINGS AND TELEOPERATOR PORTS IS ALSO ATTACHED TO CABLE REEL ASSEMBLY AND IS STOWED WITH IT AS ONE UNIT.

(b) ASSUMED RMS HEATER IS THERMOSTATICALLY CONTROLLED WITH 50% DUTY CYCLE THROUGHOUT ACTIVITY.

(c) AVERAGE POWER = $\frac{\text{TOTAL ENERGY}}{\text{TOTAL DURATION}}$

(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES SUBJECTIVELY ESTIMATED BEING PERFORMED SIMULTANEOUSLY.

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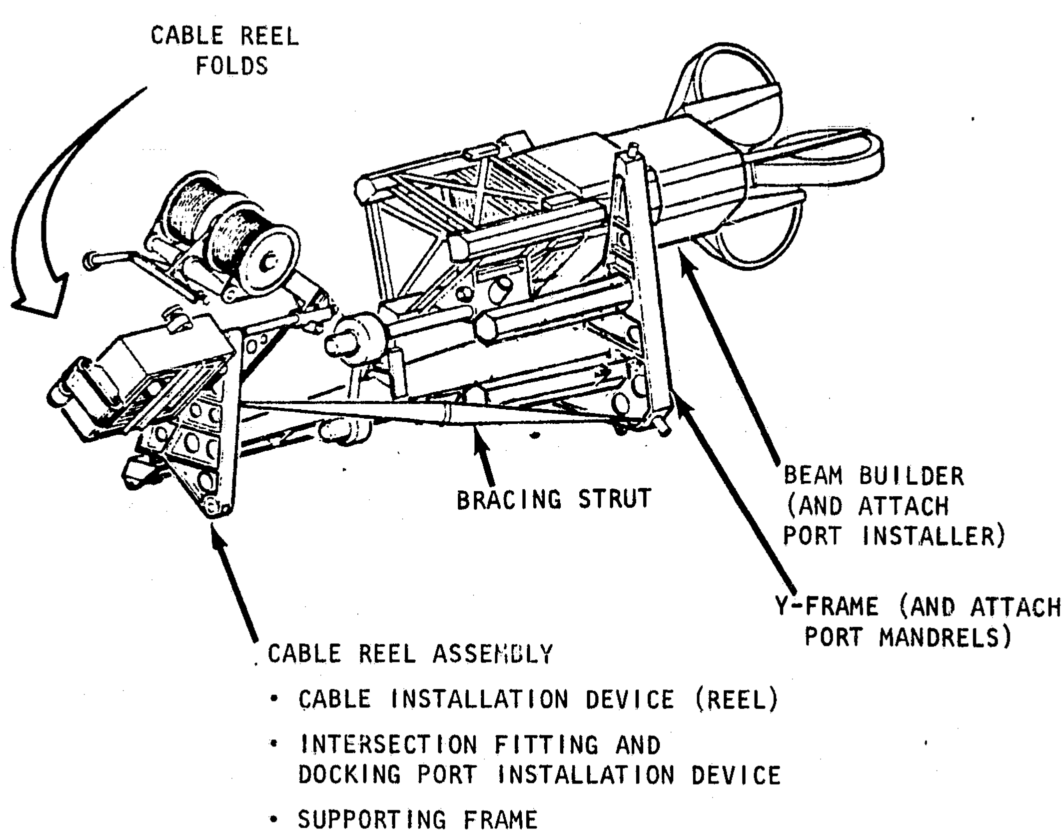
DATE:	STOW RETURN CARGO IN PAYLOAD BAY	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



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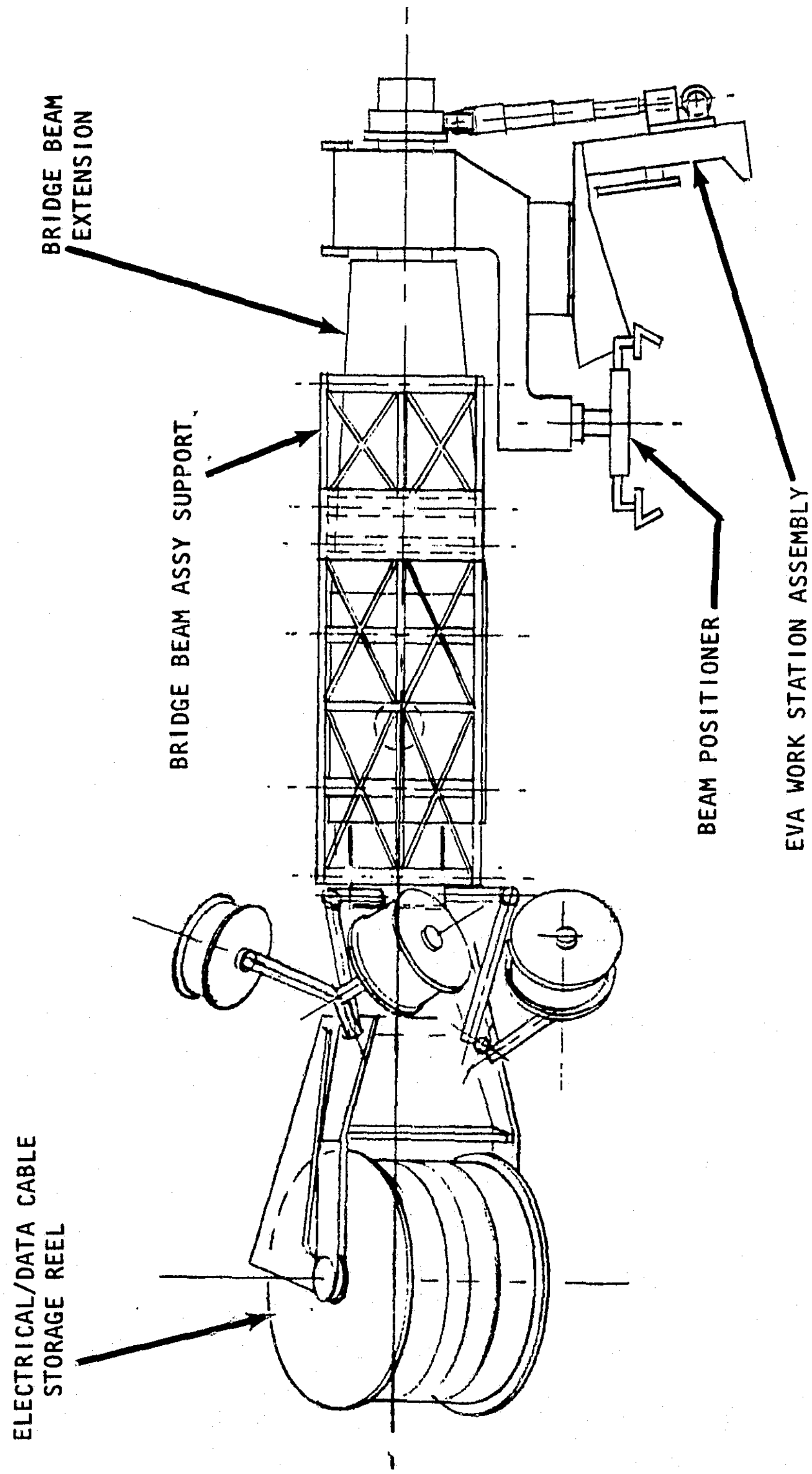
ATTACHMENT 3



FORM 994-B-1 REV 12-78

ACTIVITY 21.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

20.0 Dock Orbiter to Fixture, Prepare for Construction Operations →	21.0 Prepare Construction System for Construction Operations →	22.0 Install Forward Assembly Support Structure

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Manned Remote Work Station Development Article, Final Report, Executive Summary, Grumman Aerospace Corporation Report NSS-MR-RP008, March 1979.

DESCRIPTION OF ACTIVITY

This activity covers all operations necessary to prepare the construction system for construction operations. (see Attachment 1)

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system
3. RMS with astronaut cherry picker

TIMELINE: 60 minutes (see Attachment 1)

POWER/ENERGY

Peak power, 2.771 kW; average power, 1.890 kW; energy, 6803 kJ
(see Attachment 1)

CREW LOAD

IVA astronaut—60 minutes, continuous
EVA astronaut—none

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Tri-beam construction fixture system
2. RMS with astronaut cherry picker and end effectors

ATTACHMENT 1

PREPARE CONSTRUCTION SYSTEM FOR CONSTRUCTION OPERATIONS (ACTIVITY 21.0) SHEET 1 OF 2

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. BRING RMS FROM ITS FINAL POSITION AT THE END OF DOCKING OPERATIONS INTO A POSITION AFFORDING AN AN ADVANTAGEOUS VIEW OF THE PRELIMINARY ELECTRIC CHECKOUT TO FOLLOW.	300	0.845 (a) 1.050 (b) 0.033 (k) 0.173 (j) 0.200 (f) 0.400 (g) 2.701	0.845 (a) 0.525 (b) 0.023 (k) 0.173 (j) 0.200 (f) 0.400 (g) 2.166	650
2. A PRELIMINARY ELECTRICAL CHECK OF THE CONSTRUCTION FIXTURE ELECTRICAL SYSTEM MUST BE PERFORMED TO CONFIRM THAT A SATISFACTORY ELECTRICAL CONNECTION WAS MADE AT DOCKING; THIS CHECK WILL INCLUDE CONSTRUCTION FIXTURE TV AND LIGHTING, BUT WILL NOT INCLUDE PLATFORM TRANSLATION DRIVE SYSTEM OR THE CONSTRUCTION FIXTURE ROTATION DRIVE.	600	1.050 (b) 0.033 (k) 0.033 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.889	0.525 (b) 0.023 (k) 0.023 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.344	806
3. TO REDUCE THE DANGER OF COLLISON BETWEEN THE RMS AND THE RCS BOOMS OF THE LIBRATION DAMPING SYSTEM WHICH EXTEND OUT FROM THE CONSTRUCTION FIXTURE, THESE BOOMS MUST BE RETRACTED INTO THE STOWED POSITION.	300	1.050 (b) 0.033 (k) 0.033 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.889	0.525 (b) 0.023 (k) 0.023 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.344	403
4. MANEUVER THE RMS INTO POSITION AND ATTACH THE CHERRY PICKER WHICH IS STOWED APPROXIMATELY IN THE CENTER OF THE ORBITER CARGO BAY; PROPER ATTACHMENT IS CONFIRMED BY A CHECKOUT OF CHERRY PICKER FUNCTIONS. AT COMPLETION OF CHECKOUT, THE CHERRY PICKER MUST BE PARKED AS NEAR AS PRACTICAL TO THE AIRLOCK DOOR AND ADJACENT TO HANDHOLDS WHICH WILL PERMIT THE EVA ASTRONAUT TO EGRESS AND CLIMB INTO POSITION ABOARD IT.	1800	0.845 (a) 1.050 (b) 0.070 (k) 0.033 (h) 0.173 (j) 0.200 (f) 0.400 (g) 2.771	0.845 (a) 0.525 (b) 0.057 (k) 0.023 (h) 0.173 (j) 0.200 (f) 0.400 (g) 2.223	4001

ACTIVITY 21.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
5. WHEN THE CHERRY PICKER IS READY TO RECEIVE HIM, THE EVA ASTRONAUT EGRESSES FROM THE AIRLOCK AND PROCEEDS VIA THE HANDHOLDS TO IT AND POSITIONS HIMSELF ABOARD; AN ON-BOARD FUNCTIONAL CHECK IS PERFORMED AND THEN THE CHERRY PICKER MANEUVERED INTO POSITION FOR THE NEXT ACTIVITY.	600	1.050 (b) 0.033 (h) 0.070 (c) 0.173 (j) 0.200 (f) 0.400 (g) 0.180 (i) 2.106	0.525 (b) 0.023 (h) 0.070 (c) 0.173 (j) 0.200 (f) 0.400 (g) 0.180 (i) 1.571	943
SUMMARY	3600 (60 MIN.)	2.771 (d)	1.890 (e)	6803

NOTES

(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER

(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) ORBITER LIGHTS
(g) CONSTRUCTION FIXTURE LIGHTS
(h) CONSTRUCTION FIXTURE TV AND CAMERA
(j) RMS LIGHTS
(k) RMS TV AND HEATER
(i) CHERRY PICKER LIGHTS

Satellite Systems Division
Space Systems Group

Rockwell International

CONSTRUCTION ACTIVITY DATA SHEET 22.0

PROJECT ENGINEERING & TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

21.0 Prepare Construction Systems for Construction Operations →	22.0 Install Forward Support Structure →	23.0 Install Forward Assembly to Support Structure

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-59, Forward Assembly

DESCRIPTION OF ACTIVITY

The activity consists of removing the folded forward support structure from the orbiter bay and installing it to the forward end of the tri-beam platform (see Attachment 4 for sequence and description of tasks).

CONSTRUCTION SUPPORT EQUIPMENT

RMS, Cherry Picker & Lighting

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TIMELINE

77.5 minutes (see Attachment 4)

POWER/ENERGY

Peak power 2.2 kW; average power 1.6 kW; energy 7300 kJ (see Attachment 4)

CREW LOAD

One man continuous EVA

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

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CHECKED BY:		ACTIVITY 22.0
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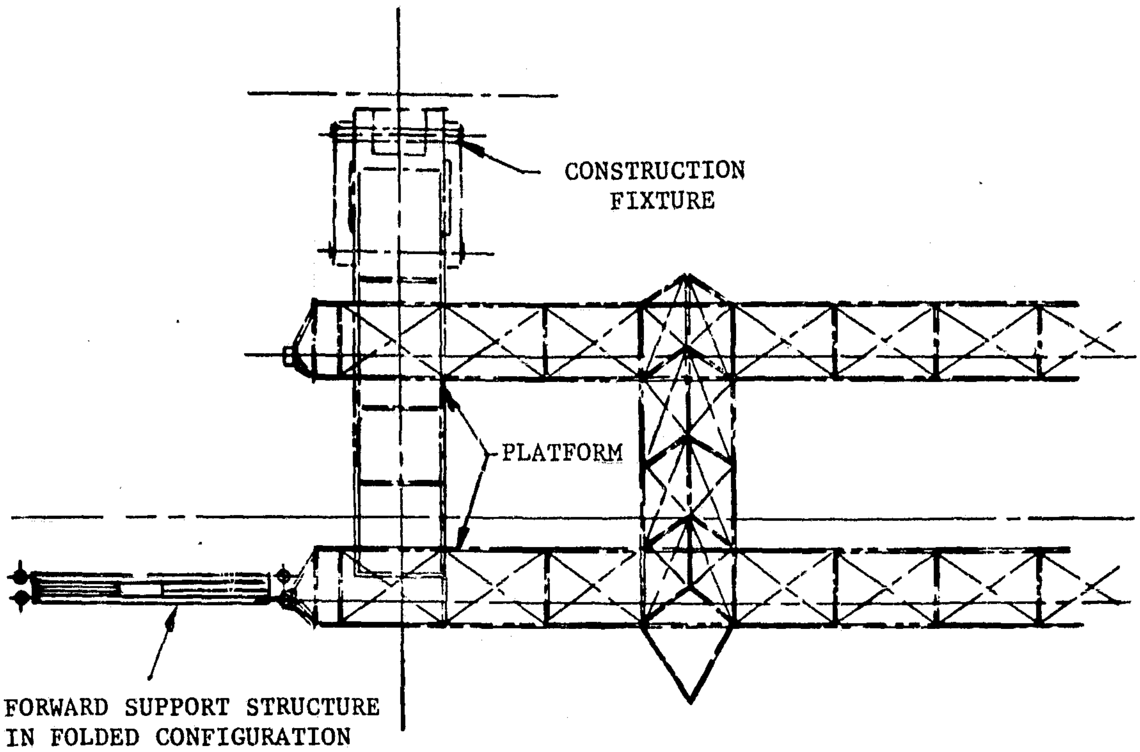
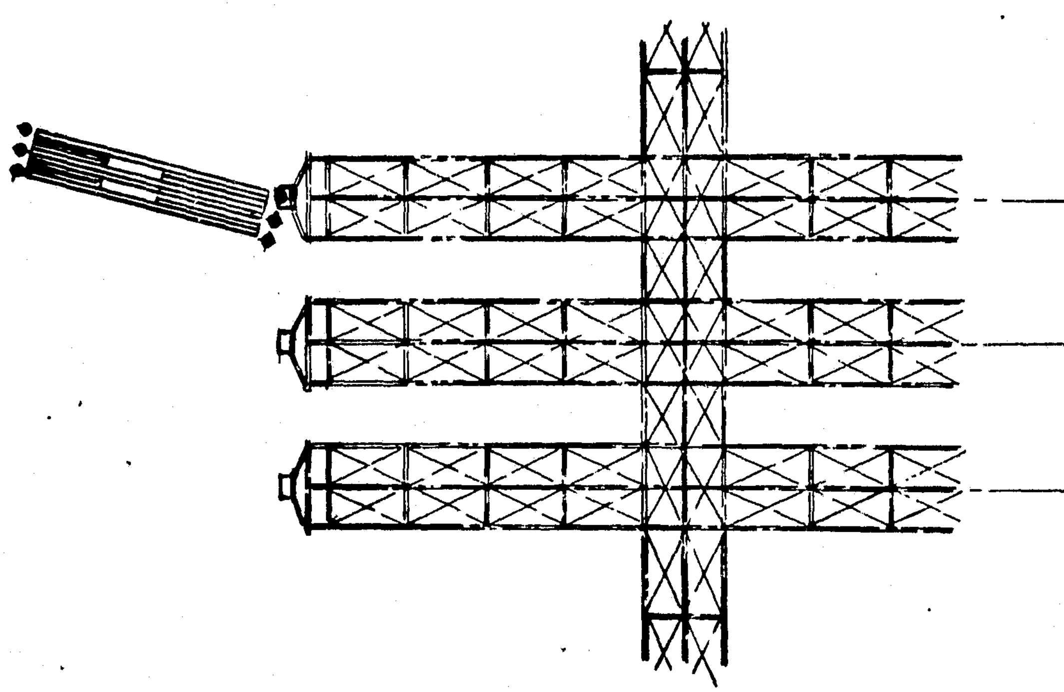
REF.		DWG. NO.

ATTACHMENT 1





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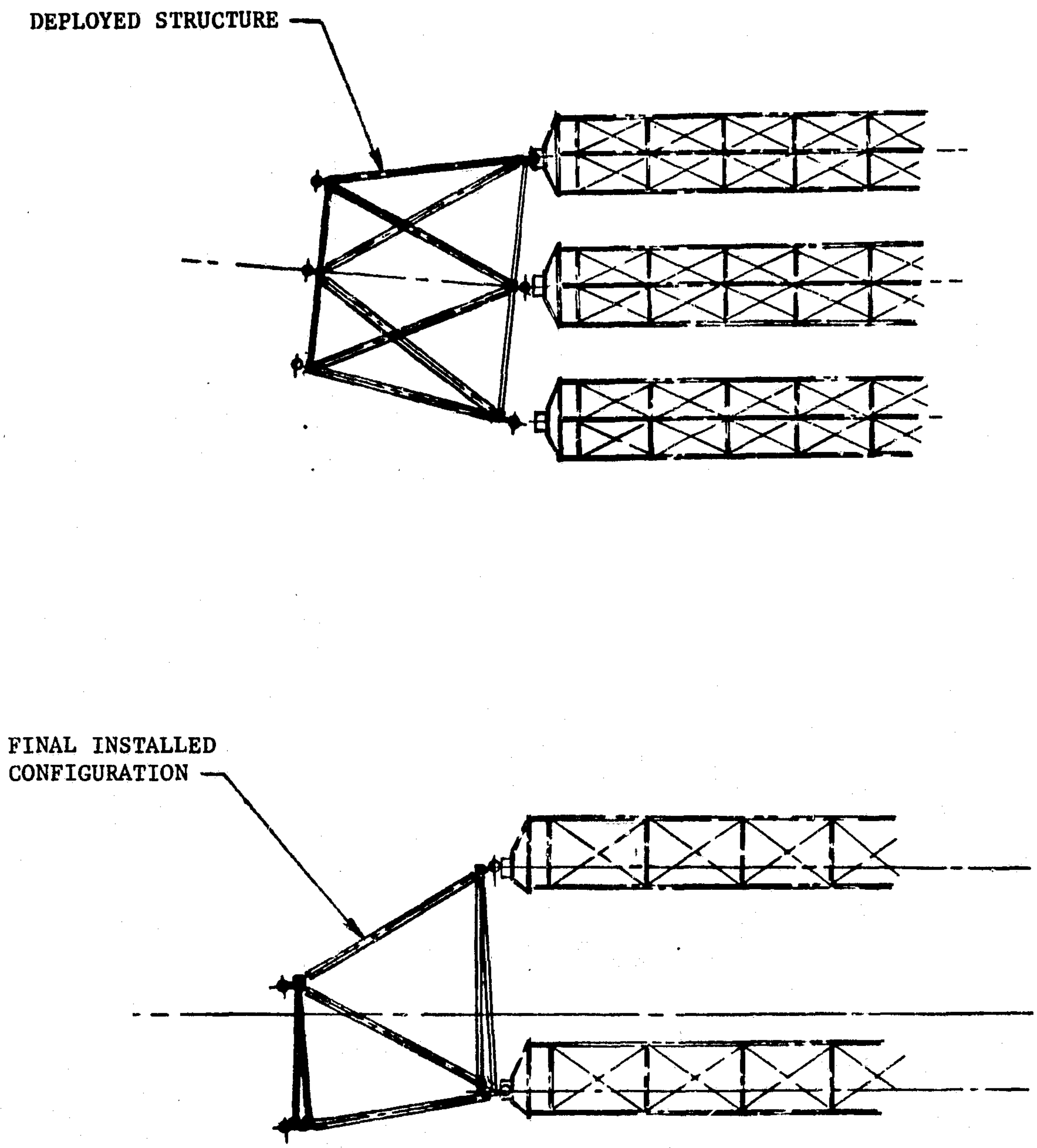
ATTACHMENT 2



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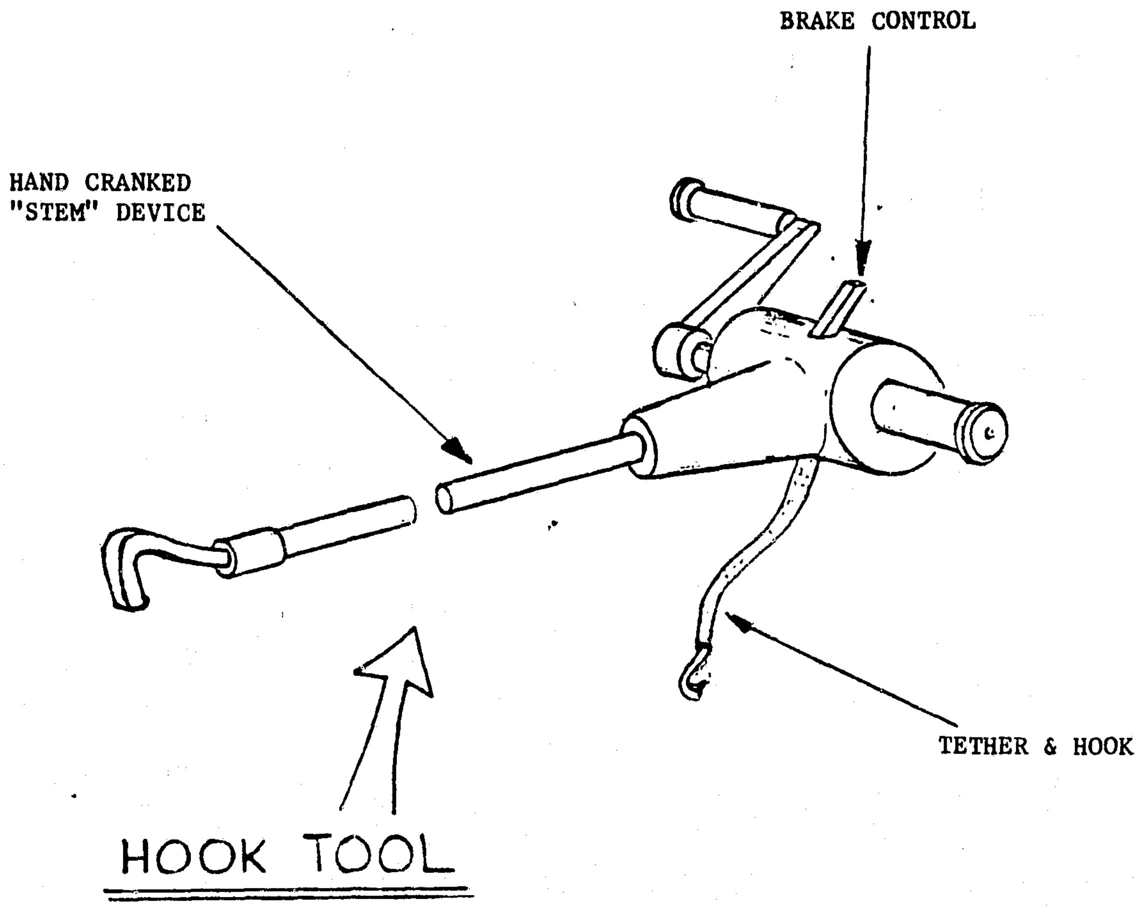
ATTACHMENT 3



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ATTACHMENT 4

Task Description	Duration (Sec.)	Peak Power (kW)	Avg. Power (kW)	Energy (kJ)
1. Move the EVA astronaut in the cherry picker to the folded forward support structure stowed in the orbiter bay and grasp it with the stabilizer arm of the cherry picker	600	.845(a) 1.050(b) .250(c)	.845(a) .525(b) .250(c)	507 315 150
2. By remote control from the orbiter crew cabin release the electro-mechanical latches which retain the forward support structure in its stowed location	30	.02(f) 1.050(b) .250(c)	.02 .525(b) .250(c)	6 16 8
3. Transport the folded forward support structure to the forward end of the platform Position the structure as shown on Attachment 1	1200	.845(a) 1.050(b) .250(c)	.845(a) .525(b) .250(c)	1014 630 300
4. Using the stabilizer arm, install the ball joint at the end of the forward support structure into the ball socket on the attach port of the platform longitudinal. The ball will automatically lock into the socket when it is inserted	300	.845(a) 1.050(b) .250(c)	.845(a) .525(b) .250(c)	253.5 157.5 75
5. Using the stabilizer arm, rotate the folded forward support structure about the installed ball joint so that the structure can be unfolded without collision.	120	.845(a) 1.050(b) .250(c)	.845(a) .525(b) .250(c)	101.4 63 30
6. Unclip the hook tool (see Attachment 3) from its stowed position on the cherry picker and use it to manually pull on the latch which secures the structure in its folded configuration. Restow the tool. The structure will unfold to its deployed configuration	300	1.050(b) .250(c)	.525(b) .250(c)	157.5 75

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REF.		DWG. NO.

ATTACHMENT 4

Task Description	Duration (Sec.)	Peak Power (kW)	Avg. Power (kW)	Energy (kJ)
7. Wait until the deployed structure is quiescent and release it from the grasp of the cherry picker. Move the cherry picker to the grasp point near the second ball joint and grasp the structure with the stabilizer	600	.845(a) 1.050(b) .250(c)	.845(a) .525(b) .250(c)	507 315 150
8. Install the second ball joint in similar fashion to Step 4 (see Attachment 2)	300	.845(a) 1.050(b) .250(c)	.845(a) .525(b) .250(c)	253.5 157.5 75
9. Install the third ball joint in similar fashion to Steps 7 and 4 (see Attachment 2)	900	.845(a) 1.050(b) .250(c)	.845 .525 .250	760.5 472.5 225
10. Release the stabilizer arm and move the cherry picker away from the structure	300	.845(a) 1.050(b) .250(c)	.845 .525 .250	253.5 157.5 75
SUMMARY	4650	2.165(d)	1.56(e)	7260.9

NOTES:

(a) Basic RMS
(b) RMS Heater
(c) Cherry Picker
(d) Peak power summary based upon peak power of individual activities, subjectively estimated, being performed simultaneously
(e) Average Power = $\frac{\text{Energy Summation}}{\text{Activity Time Summation}}$

FORM 994-B-1 REV 12-78

ACTIVITY 23.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT Engineering and Technology Verification Platform (ETVP)

ACTIVITY

22.0 Install Forward Support Structure →	23.0 Install Forward Assembly to Support Structure →	24.0 Connect Forward Assembly to Main Electric Buses

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-59, Forward Assembly
4. Drawing 42662-57, Control Module Assembly

DESCRIPTION OF ACTIVITY

The activity consists of removing the forward assembly from the orbiter cargo bay with the RMS/cherry picker combined system and installing it on the forward support structure. Specific steps in the operation are delineated in Attachment 1. Attachments 2 through 7 illustrate details relating to the physical attachment process.

TIMELINE: 80 minutes, 30 seconds (see Attachment 1)

POWER/ENERGY

Peak power, 2.1 kW; average power, 1.6 kW; energy, 7800 kJ (see Attachment 1)

CREW LOAD: EVA—One man continuously

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ACTIVITY 23.0

ATTACHMENT 1

SHEET 1 OF 2

TIME, POWER, AND ENERGY ESTIMATION FOR INSTALLATION OF THE FORWARD BAY

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MOVE THE EVA ASTRONAUT IN THE CHERRY PICKER TO THE FWD ASSY STOWED IN THE ORBITER BAY & GRASP IT WITH THE CHERRY PICKER STABILIZER ARM.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
2. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE ELECTROMECHANICAL LATCHES WHICH RETAIN THE FORWARD ASSEMBLY IN ITS STOWED LOCATION.	30	0.02 (f) 1.050 (b) 0.250 (c)	0.02 (f) 0.525 (b) 0.250 (c)	6 16 8
3. TRANSPORT THE FORWARD ASSEMBLY TO NEAR ITS INSTALLED LOCATION ON THE FWD SUPPORT STRUCTURE	1200	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	1014 630 300
4. UNCLIP THE HOOK TOOL FROM ITS STOWED LOCATION ON THE CHERRY PICKER & USE IT TO MANUALLY ACTIVATE THE 2ND POSITION CONTROL OF THE CABLE TRAY; THE TRAY WILL AUTOMATICALLY DEPLOY AS SHOWN IN (2) ON ATTACHMENT 5. RESTOW THE TOOL.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
5. USE THE STABILIZER ARM TO INSTALL THE 1ST BALL SOCKET OF THE CM TO THE BALL JOINT OF THE SUPPORT STRUCTURE; THE BALL WILL AUTOMATICALLY LOCK IN THE SOCKET WHEN IT IS INSERTED.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
6. WAIT UNTIL THE FWD ASSY IS QUIESCENT, THEN RELEASE THE STABIL. ARM; MOVE CHERRY PICKER TO NEAR THE 2ND BALL SOCKET AND GRASP THE CM.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
7. INSTALL THE 2ND & 3RD BALL JOINTS IN SIMILAR FASHION TO STEPS 5, 6, 5.	1200	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	1014 630 300
8. UNCLIP HOOK TOOL FROM ITS STOWED POSITION ON THE CHERRY PICKER; USE IT TO MANUALLY ACTIVATE THE 3RD POSITION CONTROL OF THE CABLE TRAY. THE TRAY WILL AUTOMATICALLY MOVE TO POSITION (3), AS SHOWN ON ATTACHMENT 5.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 1.050 (b) 0.250 (c)	253.5 157.5 75

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
9. USE THE HOOK TOOL TO MANUALLY ACTIVATE THE 4TH POSITION CONTROL OF THE CABLE TRAY; RESTOW THE TOOL. THE TRAY WILL AUTOMATICALLY MOVE TO POSITION (4), AS SHOWN ON ATTACHMENT 5.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 1.050 (b) 0.250 (c)	253.5 157.5 75
SUMMARY	4830 (80 MINUTES, 30 SECONDS)	2.145 (d)	1.616 (e)	7806

NOTES

(a) BASIC RMS

(b) RMS HEATER

(c) CHERRY PICKER

(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) LATCH

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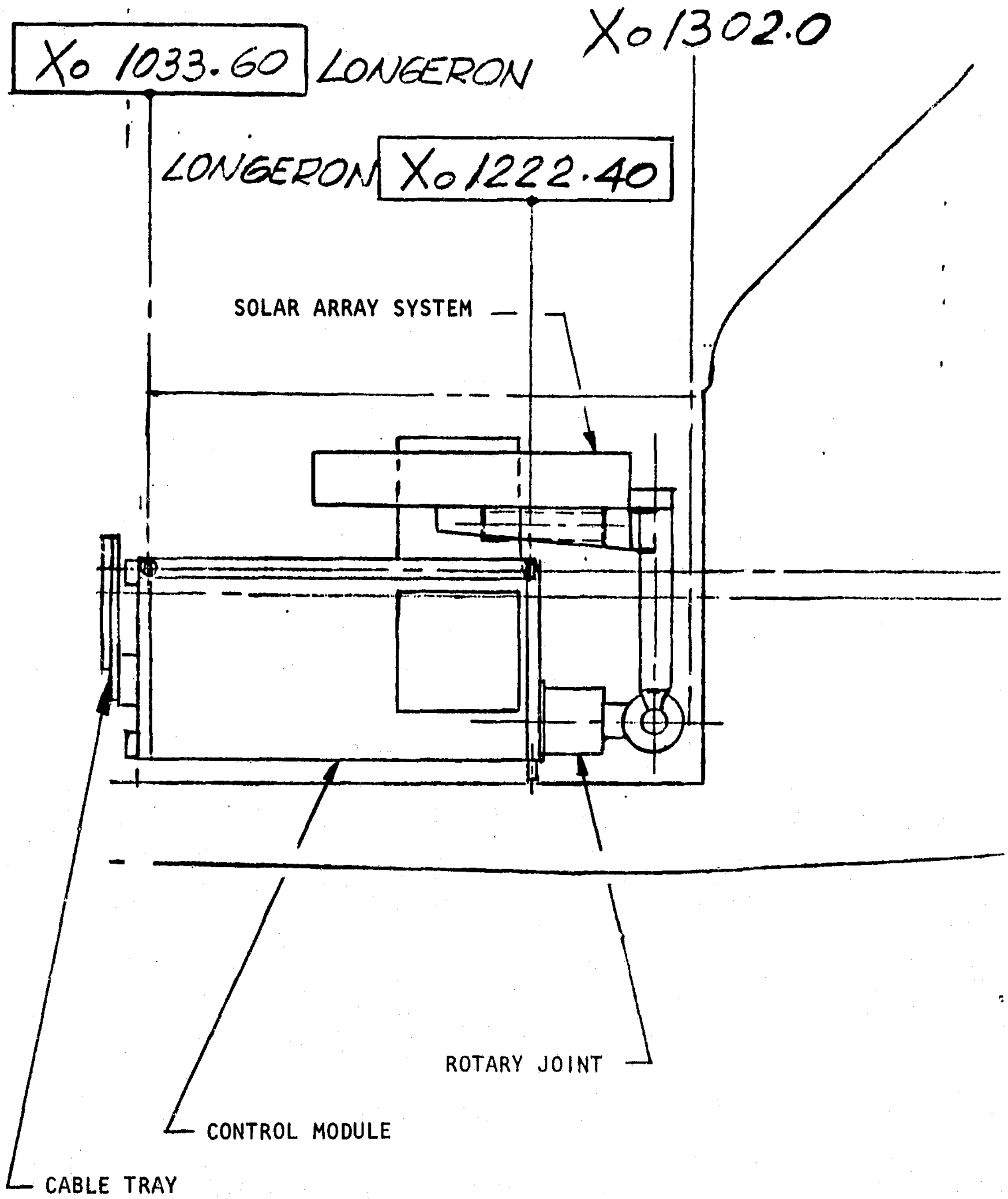
DATE:	INSTALL FORWARD ASSEMBLY TO SUPPORT STRUCTURE	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

STOWED CONFIGURATION OF FWD ASSY IN ORBITER CARGO BAY



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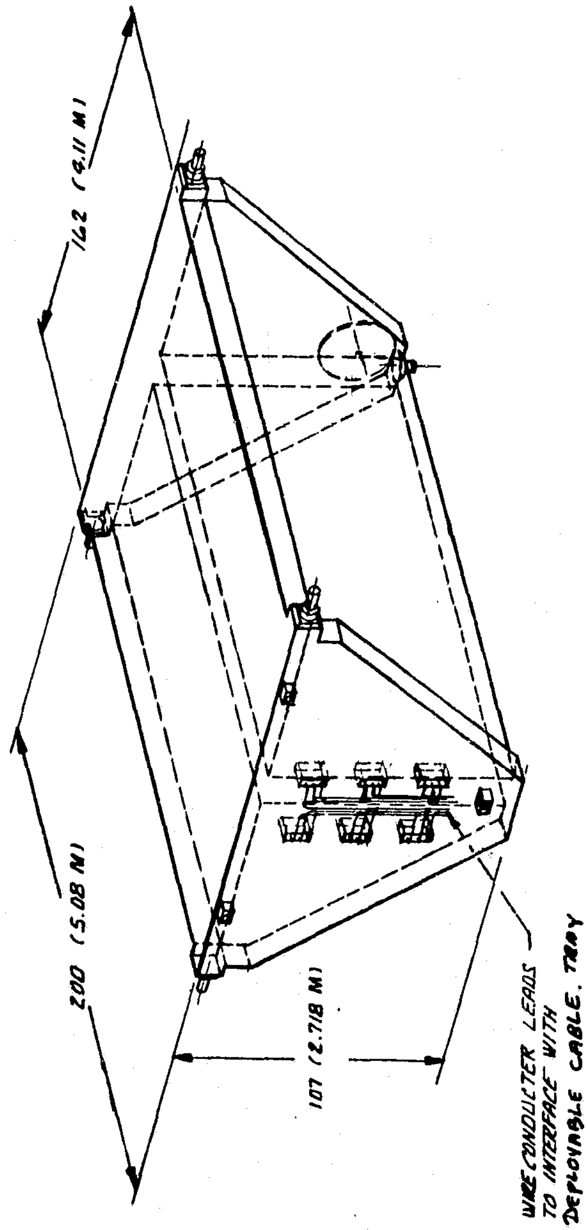
ATTACHMENT 3



CONTROL MODULE STRUCTURE CONFIG

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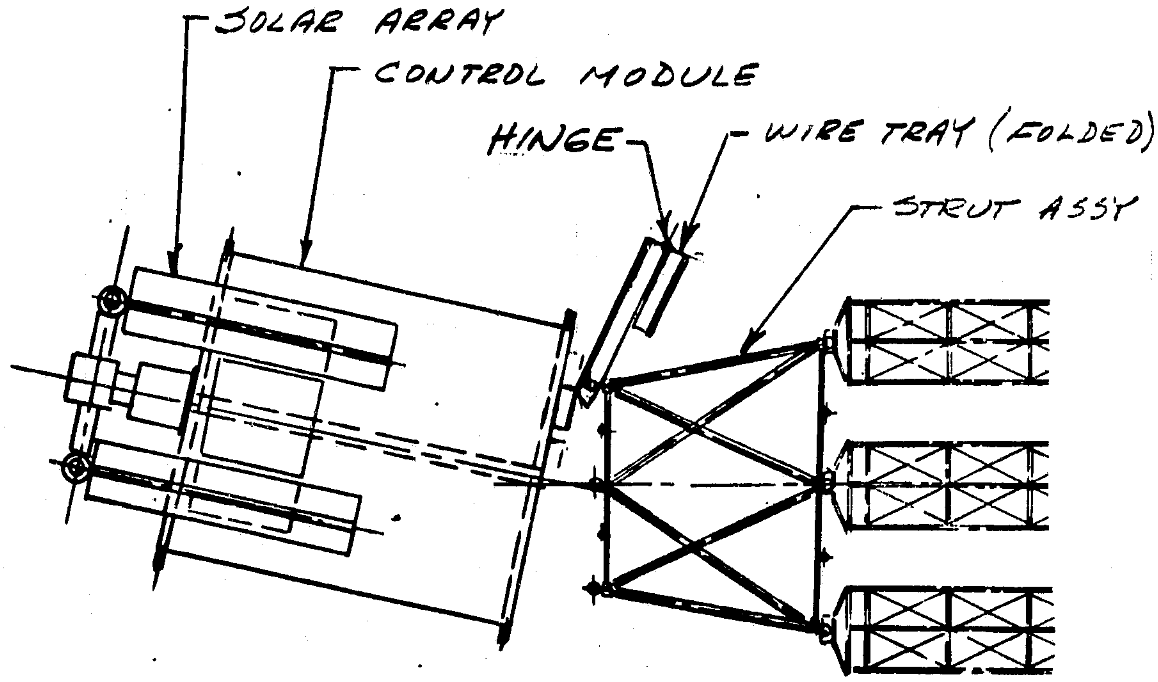
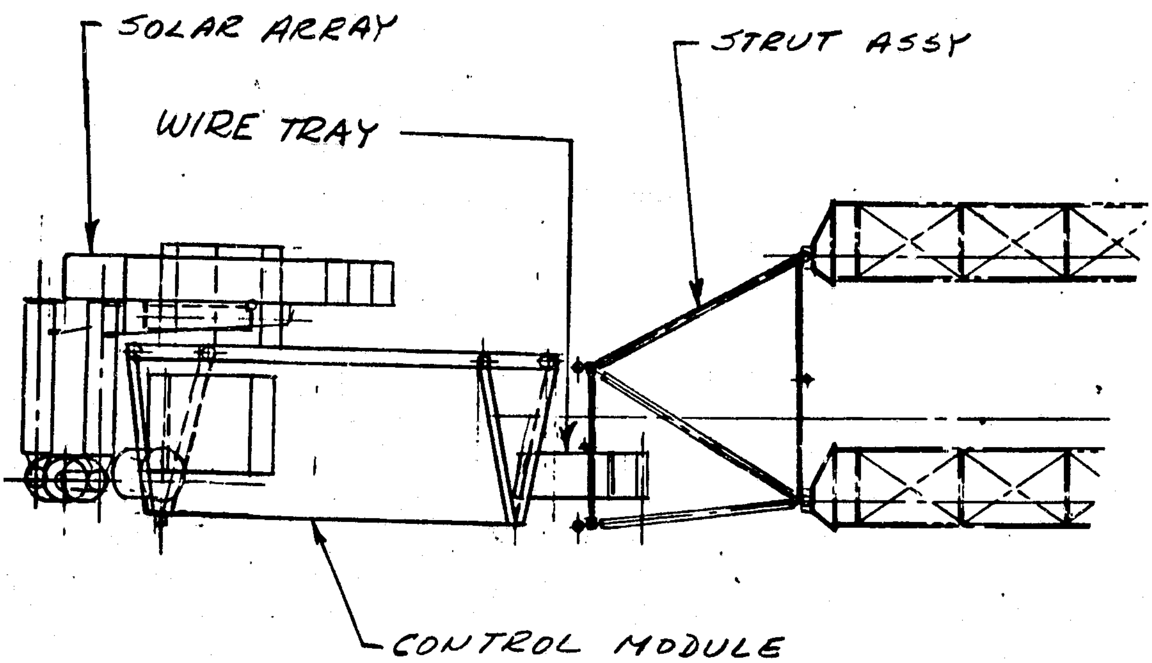
		DWG. NO.

ATTACHMENT 4





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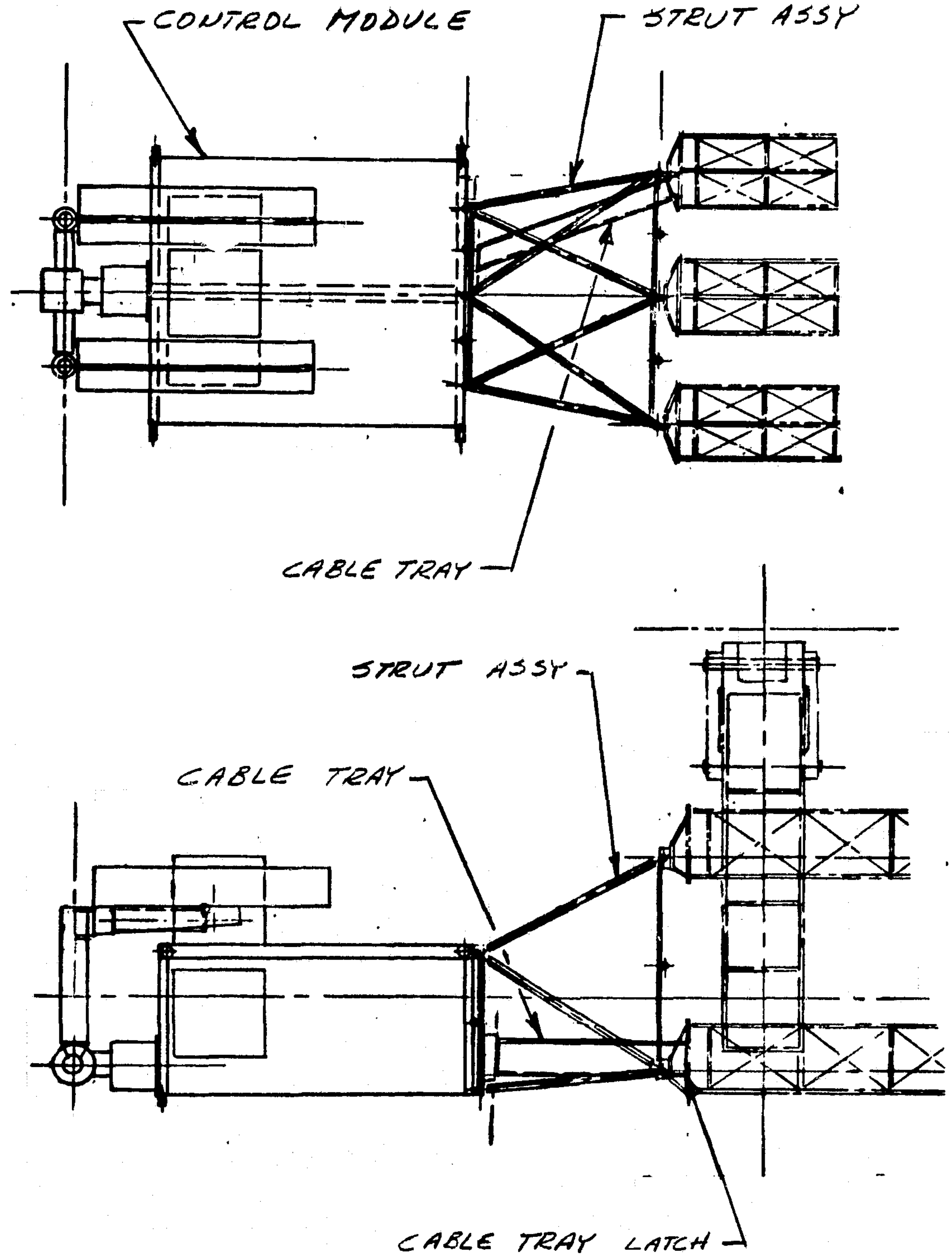
ATTACHMENT 5



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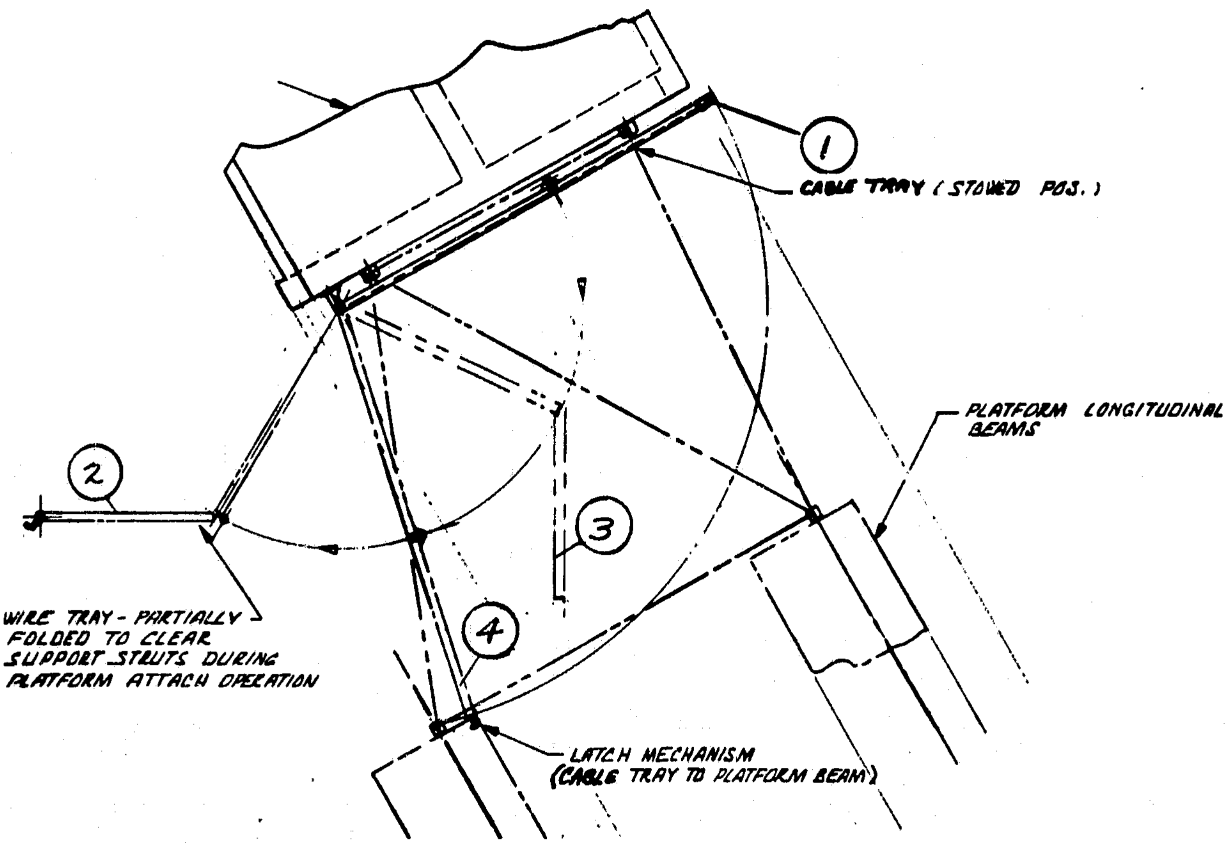
ATTACHMENT 6



THE FOUR POSITIONS OF THE CABLE TRAY

(1) STOWED
(2) DEPLOYED FOR CONTROL MODULE INSTALLATION TO SUPPORT TRUSS
(3) INTERMEDIATE POSITION
(4) STRAIGHTENED POSITION FOR LATCHING

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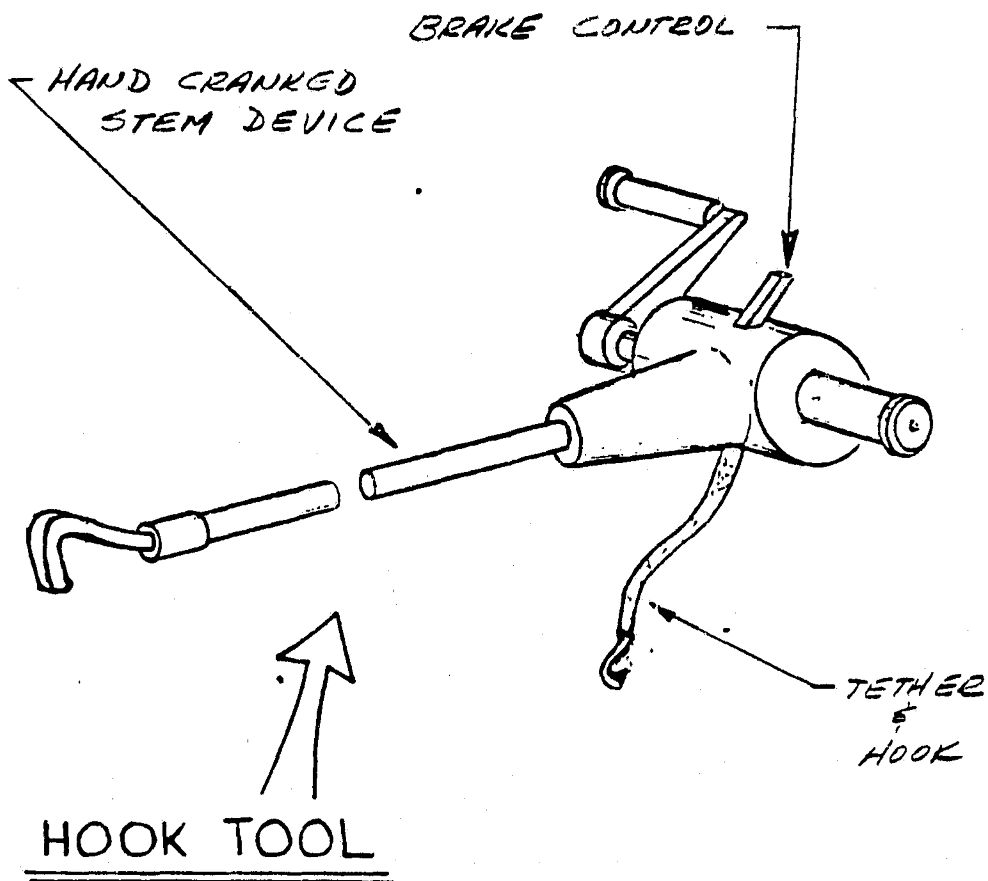
ATTACHMENT 7



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ACTIVITY 24.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT Engineering and Technology Verification Platform (ETVP)

ACTIVITY

23.0 Install Forward Assembly Support Structure	24.0 Connect Forward Assembly to Main Electric Buses	25.0 Translate Platform

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Drawing 42662-59, Forward Assembly and Installation
4. Drawing 42662-57, Control Module Assembly

DESCRIPTION OF ACTIVITY

After the cable tray is manually locked in place, there will be seven connectors that will be individually engaged by the EVA astronaut, as discussed in Attachment 1.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system
3. RMS with astronaut cherry picker

TIMELINE: 41 minutes (see Attachment 2)

POWER/ENERGY

Peak power (occurring during Tasks 1 and 4), 2.145 kW; average power, 1.187 kW; energy, 2921 kJ —see Attachment 2.

CREW LOAD

EVA astronaut: 41 minutes, continuously
IVA astronaut: 20 minutes, monitoring

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Electrical connector for EVA astronaut manual operations
2. Cherry picker

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CHECKED BY:		ACTIVITY 24.0
DATE:	CONNECT FORWARD ASSEMBLY TO MAIN ELECTRICAL BUSES	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

DISCUSSION OF ACTIVITY

At the end of the preceding activity (23.0—Installation of Forward Assembly to Support Structure), the cable tray has been brought into final position, but not yet locked to the structure. The first task to be accomplished by the EVA astronaut in this activity will be to manually latch the cable tray in place. Once the cable tray is latched, the cable tiedowns can be released, which will make the cables with their connectors available for engagement to the mating connectors on the main bus wiring.

ACTIVITY 24.0

ATTACHMENT 2

TIME, POWER, AND ENERGY ESTIMATION FOR CONNECTING FORWARD ASSEMBLY TO MAIN ELECTRICAL BUSES

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MANEUVER CHERRY PICKER, WITH EVA ASTRONAUT, TO A POSITION WITHIN REACH OF CABLE TRAY LATCH.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75.0
2. MANUALLY LATCH CABLE TRAY IN PLACE, MECHANICALLY ATTACHING IT TO THE FORWARD SUPPORT STRUCTURE, AS ILLUSTRATED IN STEP 4, SHEET 1 OF DRAWING NO. 42662-59.	300	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	157.5 75.0
3. THE CABLE PIGTAIL ENDS, TERMINATED WITH ELECTRICAL CONNECTORS, WILL BE TRANSPORTED CONTAINED BY QUICK-RELEASE TIEDOWNS. THIS TASK REMOVES THOSE TIEDOWNS, MAKING THE PIGTAILS AVAILABLE FOR CONNECTION TO THE MAIN ELECTRICAL BUSES.	60	1.05 (b) 0.250 (c)	0.525 (b) 0.250 (c)	31.5 15.0
4. THE MAIN TASK OF THIS ACTIVITY IS TO ENGAGE THE ELECTRICAL CONNECTORS LEADING FROM THE FORWARD ASSEMBLY TO THE MAIN DISTRIBUTION SYSTEM ON THE PLATFORM. AT COMPLETION OF ELECTRICAL CONNECTIONS, THE CHERRY PICKER IS RETRACTED TO A POSITION CLEAR OF PLATFORM TRANSLATION.	900 1800 1800	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	760.5 945.0 450.0
SUMMARY	2460 (41 MIN.)	2.145 (d)	1.187 (e)	2921

NOTES

(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER

(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

ACTIVITY 25.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

24.0 Connect Forward Assembly to Main Electric Buses	→	25.0 Install Bracing Struts on Port Side of Platform	→	26.0 Rotate Platform 180°

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Drawing 42662-71, Bracing Strut Installation via Cherry Picker

DESCRIPTION OF ACTIVITY

On both sides of the platform there will be installed 12 bracing struts, two struts bracing each of the six long crossbeams. This bracing is required to react the orbit transfer loads of the installed payloads. Between the installation of the pair of bracing struts at each crossbeam, the platform must be translated far enough to bring the next crossbeam within reach of the RMS/cherry picker. Attachments 1 and 4 delineate the specific steps in the activity.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system
3. RMS with astronaut cherry picker
4. Bracing strut stowage canister

TIMELINE: 10 hours, 58 minutes (see Attachment 2)

POWER/ENERGY

Peak power, 2.992 kW; average power, 2.236 kW; energy, 88,260 kJ
(see Attachment 2)

CREW LOAD

EVA astronaut—10 hours, 58 minutes (continuous)
IVA astronaut—10 hours, 58 minutes (monitoring and support activities)

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Tri-beam construction fixture system
2. RMS with astronaut cherry picker
3. Bracing strut stowage canister

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DATE:	INSTALL BRACING STRUTS ON PORT SIDE OF PLATFORM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

Activity 25.0 includes a total of 78 identified tasks which may be grouped into six sets of 13 basic tasks—one set being required for the installation of the pair of bracing struts on each end of each of the crossbeams. With the exception of small differences in the first task of each set (due to a slight variation in the distance that the platform must be translated to bring a crossbeam within reach of the RMS/cherry picker), the duration, power requirements, etc., of each set of 13 basic tasks are the same.

Attachment 3 presents a detail breakdown and summary of the construction support equipment utilization and total payload power requirements for a typical set of 13 basic tasks. The peak power, average power, and energy summaries for each task are used as entries on Attachment 2. Attachment 3 shows some commonalities of the various tasks—for example, if the RMS is active the peak power requirement will be 2.992 kW and the average power requirement, 2.454 kW. This is the case for Tasks 2, 3, 4, 5, 7, 8, 9, 10, 11, and 13. Excepting the first task, if the RMS is inactive, the peak power requirement will be 2.147 kW and the average power requirement will be 1.609 kW. This is the case for Tasks 6 and 12. For the first task, the peak power requirement is 2.262 kW and the average power requirement is 1.724 kW. This differs from Tasks 6 and 12 only in that the construction fixture drive rolls are active for translation of the platform.

ACTIVITY 25.0 ATTACHMENT 2 SHEET 1 OF 3

TIME, POWER, AND ENERGY ESTIMATION FOR INSTALLING BRACING STRUTS ON PORT SIDE OF PLATFORM

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. TRANSLATE PLATFORM INTO POSITION	240	2.262	1.724	413.76
2. GRASP STRUT A	300	2.992	2.454	736.20
3. TRANSPORT STRUT A TO PLATFORM	1080	2.992	2.454	2650.32
4. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
5. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
6. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
7. RMS RETURN TO POSITION	300	2.992	2.454	736.20
8. GRASP STRUT B	300	2.992	2.454	736.20
9. TRANSPORT STRUT B TO PLATFORM	1080	2.992	2.454	2650.32
10. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
11. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
12. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
13. RMS RETURN TO POSITION	300	2.992	2.454	736.20
14. TRANSLATE PLATFORM INTO POSITION	360	2.262	1.724	620.64
15. GRASP STRUT A	300	2.992	2.454	736.20
16. TRANSPORT STRUT A TO PLATFORM	1080	2.992	2.454	2650.32
17. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
18. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
19. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
20. RMS RETURN TO POSITION	300	2.992	2.454	736.20
21. GRASP STRUT B	300	2.992	2.454	736.20
22. TRANSPORT STRUT B TO PLATFORM	1080	2.992	2.454	2650.32
23. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
24. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
25. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
26. RMS RETURN TO POSITION	300	2.992	2.454	736.20
27. TRANSLATE PLATFORM INTO POSITION	720	2.262	1.724	1241.28
28. GRASP STRUT A	300	2.992	2.454	736.20
29. TRANSPORT STRUT A TO PLATFORM	1080	2.992	2.454	2650.32
30. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
31. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
32. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
33. RMS RETURN TO POSITION	300	2.992	2.454	736.20

ACTIVITY 25.0

ATTACHMENT 1

SHEET 2 OF 3

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
34. GRASP STRUT B	300	2.992	2.454	736.20
35. TRANSPORT STRUT B TO PLATFORM	1080	2.992	2.454	2650.32
36. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
37. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
38. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
39. RMS RETURN TO POSITION	300	2.992	2.454	736.20
40. TRANSLATE PLATFORM INTO POSITION	720	2.262	1.724	1241.28
41. GRASP STRUT A	300	2.992	2.454	736.20
42. TRANSPORT STRUT A TO PLATFORM	1080	2.992	2.454	2650.32
43. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
44. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
45. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
46. RMS RETURN TO POSITION	300	2.992	2.454	736.20
47. GRASP STRUT B	300	2.992	2.454	736.20
48. TRANSPORT STRUT B TO PLATFORM	1080	2.992	2.454	2650.32
49. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
50. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
51. ADJUST AND ENGAGE SECOND BALL JOINT	500	2.147	1.609	965.40
52. RMS RETURN TO POSITION	300	2.992	2.454	736.20
53. TRANSLATE PLATFORM INTO POSITION	720	2.262	1.724	1241.28
54. GRASP STRUT A	300	2.992	2.454	736.20
55. TRANSPORT STRUT A TO PLATFORM	1080	2.992	2.454	2650.32
56. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
57. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
58. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
59. RMS RETURN TO POSITION	300	2.992	2.454	736.20
60. GRASP STRUT B	300	2.992	2.454	736.20
61. TRANSPORT STRUT B TO PLATFORM	1080	2.992	2.454	2650.32
62. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
63. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
64. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
65. RMS RETURN TO POISITON	300	2.992	2.454	736.20
66. TRANSLATE PLATFORM INTO POSITION	720	2.262	1.724	1241.28

ATTACHMENT 2

ACTIVITY 25.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
67. GRASP STRUT A	300	2.992	2.454	736.20
68. TRANSPORT STRUT A TO PLATFORM	1080	2.992	2.454	2650.32
69. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
70. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
71. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
72. RMS RETURN TO POSITION	300	2.992	2.454	736.20
73. GRASP STRUT B	300	2.992	2.454	736.20
74. TRANSPORT STRUT B TO PLATFORM	1080	2.992	2.454	2650.32
75. ENGAGE FIRST BALL JOINT	240	2.992	2.454	588.96
76. RELEASE AND POSITION CHERRY PICKER	480	2.992	2.454	1177.92
77. ADJUST AND ENGAGE SECOND BALL JOINT	600	2.147	1.609	965.40
78. RMS RETURN TO POSITION	300	2.992	2.454	736.20
SUMMARY	39,480 SEC 10:58 HR	2.992 (a)	2.236 (b)	88,260 kJ 24.5 kWh

NOTES

(a) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(b) $\text{AVERAGE POWER} = \frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

ATTACHMENT 3

SUMMARY OF POWER & ENERGY REQUIREMENTS BY TASK & EQUIPMENT FOR TYPICAL SET OF 13 TASKS IN ACTIVITY 25.0

	TASKS												
	1	2	3	4	5	6	7	8	9	10	11	12	13
PEAK POWER													
RMS OPERATION	-	0.845			0.845	-	0.845				0.845	-	0.845
RMS HEATER	1.050												1.050
RMS TV/HEATER	-	-	-	-	-	-	-	-	-	-	-	-	-
CONSTR. FIX. TV/HEATER	0.047												0.047
CONSTR. FIXTURE DRIVE	0.115	-	-	-	-	-	-	-	-	-	-	-	-
CONSTR. FIX. ROTATOR	-	-	-	-	-	-	-	-	-	-	-	-	-
CHERRY PICKER OPERATION	0.070												0.070
MISCELLANEOUS	-	-	-	-	-	-	-	-	-	-	-	-	-
RMS LIGHTS	-	-	-	-	-	-	-	-	-	-	-	-	-
ORBITER LIGHTS	0.200												0.200
CONSTR. FIX. LIGHTS	0.600												0.600
CHERRY PICKER LIGHTS	0.180												0.180
TOTAL PEAK POWER	2.262	2.992	2.992	2.992	2.992	2.147	2.992	2.992	2.992	2.992	2.992	2.147	2.992
AVERAGE POWER													
RMS OPERATION	-	0.845			0.845	-	0.845				0.845	-	0.845
RMS HEATER	0.525												0.525
RMS TV/HEATER	-	-	-	-	-	-	-	-	-	-	-	-	-
CONSTR. FIX. TV/HEATER	0.034												0.034
CONSTR. FIXTURE DRIVE	0.115	-	-	-	-	-	-	-	-	-	-	-	-
CONSTR. FIX. ROTATOR	-	-	-	-	-	-	-	-	-	-	-	-	-
CHERRY PICKER OPERATION	0.070												0.070
MISCELLANEOUS	-	-	-	-	-	-	-	-	-	-	-	-	-
RMS LIGHTS	-	-	-	-	-	-	-	-	-	-	-	-	-
ORBITER LIGHTS	0.200												0.200
CONSTR. FIX. LIGHTS	0.600												0.600
CHERRY PICKER LIGHTS	0.180												0.180
TOTAL AVG PWR (kW)	1.724	2.454	2.454	2.454	2.454	1.609	2.454	2.454	2.454	2.454	2.454	2.454	2.454
TOTAL ENERGY (kWh)	0.115	0.205	0.736	0.164	0.327	0.268	0.205	0.205	0.736	0.164	0.327	0.268	0.205

ATTACHMENT 4

PROCEDURES FOR INSTALLING BRACING STRUTS

Initially, the bracing strut storage canister will be rotated, by remote control from the orbiter crew compartment, to its deployed position as shown in Figure 1. The orbiter is then docked to the construction fixture. The RMS will grasp the cherry picker which will be boarded by an EVA astronaut as shown in Figure 2. Removal of the bracing struts and installation on the platform is accomplished in four phases, as described below.

1. Step A—Strut removal from storage canister and attachment of leading end to attach port at end of long crossbeam (see Figure 3).
   - Translate platform until fixture is at midpoint between first long crossbeam and short crossbeam.
   - Move RMS across payload bay, aligning cherry picker into position above the canister.
   - The cherry picker attaches to one end of a strut in the canister via the end effector at end of the stabilizer arm (see Figure 4).
   - The strut is removed clear where the RMS wrist rotates the strut into the approximate assembly plane.
   - The RMS is rotated, positioning the wrist directly below the long crossbeam.
   - The RMS wrist joint is rotated, moving strut "up" toward platform in the Y_O plane.
   - The cherry picker makes the final alignment and inserts the leading end of strut into the attachment housing.

2. Step B—Assembly of trailing end of strut to attachment at the short crossbeam extremity.
   - RMS releases leading end of strut and moves clear. The upper and lower arms of the RMS are driven so they are in a straight line.
   - The rotary joint in the upper arm of the (modified) RMS is rotated 180°, allowing elbow to be rotated in the opposite direction (see Figure 2).
   - The RMS is translated to position the cherry picker alongside the end of the short crossbeam as shown in Figure 5.
   - With cherry picker in position alongside the strut, the astronaut removes the strut length adjustment device and corrects the strut length as required for assembly, as shown in Figure 6.

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ATTACHMENT 4

- With the strut length corrected (if necessary), the device is restowed on the cherry picker and the ball end inserted into the attachment housing.

NOTE: The strut assembly described in Steps A and B is repeated an additional five times, as shown in Figure 7, and each assembly sequence is doubled, adding a second strut to the attach ports as shown in Figure 8.

3. Step C—Assembly sequence for second (or opposing) strut.

   Translate the platform until the second long crossbeam is in line with the centerline of the orbiter.

   The RMS picks up one end of strut following the sequence described in Step A.

4. Step D—Final attachment sequence for second strut.

   - The RMS releases strut and moves clear.
   - The RMS is translated in position with the cherry picker alongside the end of the short crossbeam as shown in Figure 9.
   - The remaining assembly sequence is as described in Step B.

NOTE: The strut assembly described in Steps C and D is repeated an additional five times, as shown in Figure 7, and each assembly sequence is doubled, adding a second strut to the attach ports as shown in Figure 10.

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ATTACHMENT 4

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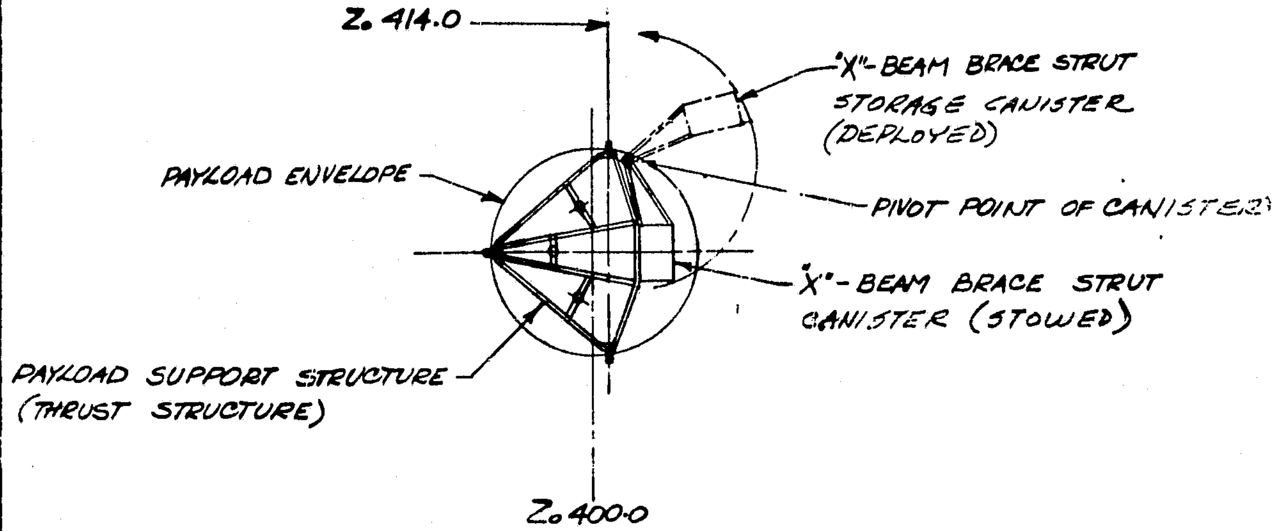
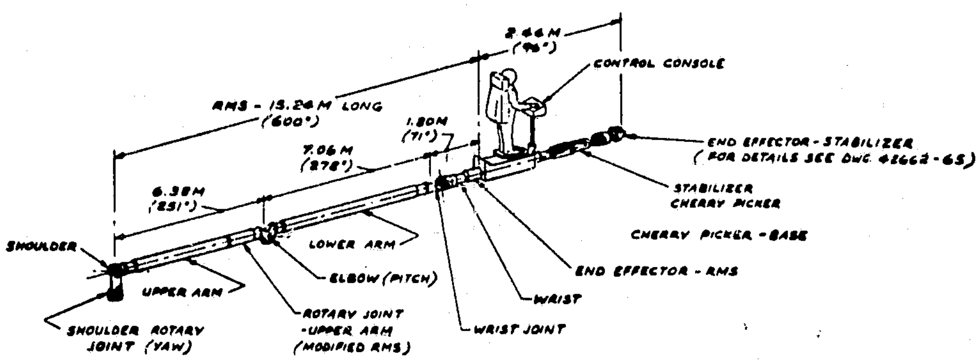


FIG. 1



RMS/CHERRY PICKER ASSEMBLY

FIG. 2

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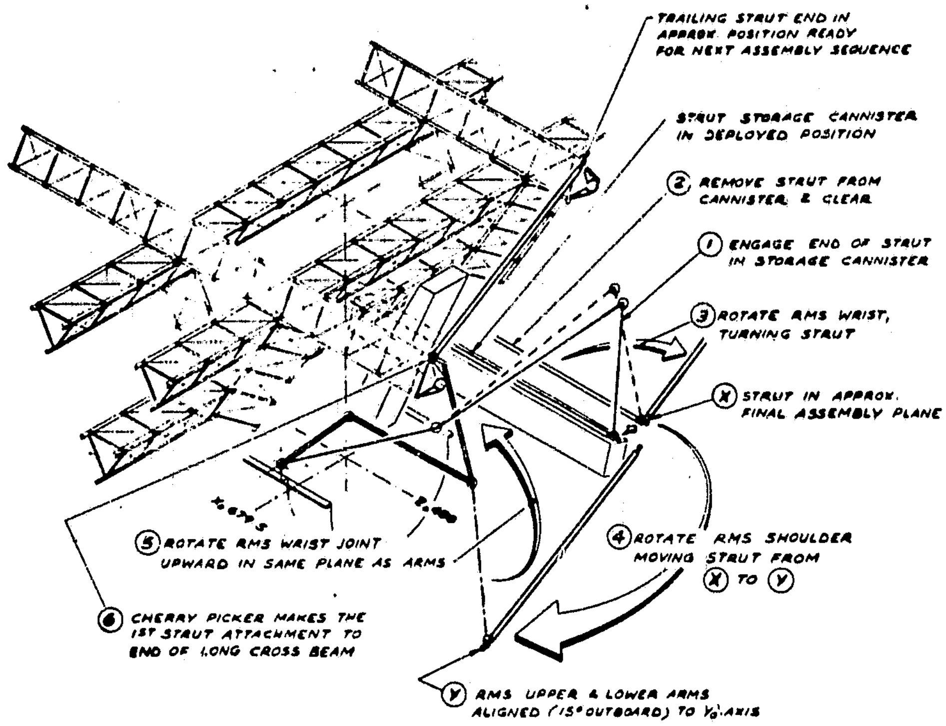
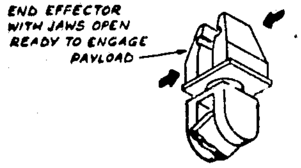
ATTACHMENT 4



STRUT REMOVAL TO 1ST ATTACHMENT PROCEEDURE.

STRUT (LEADING END) ASSEMBLY ACCOMPLISHED VIA CHERRY PICKER

FIG. 3



END EFFECTOR (STABILIZER) DETAIL

FIG. 4

ATTACHMENT 4

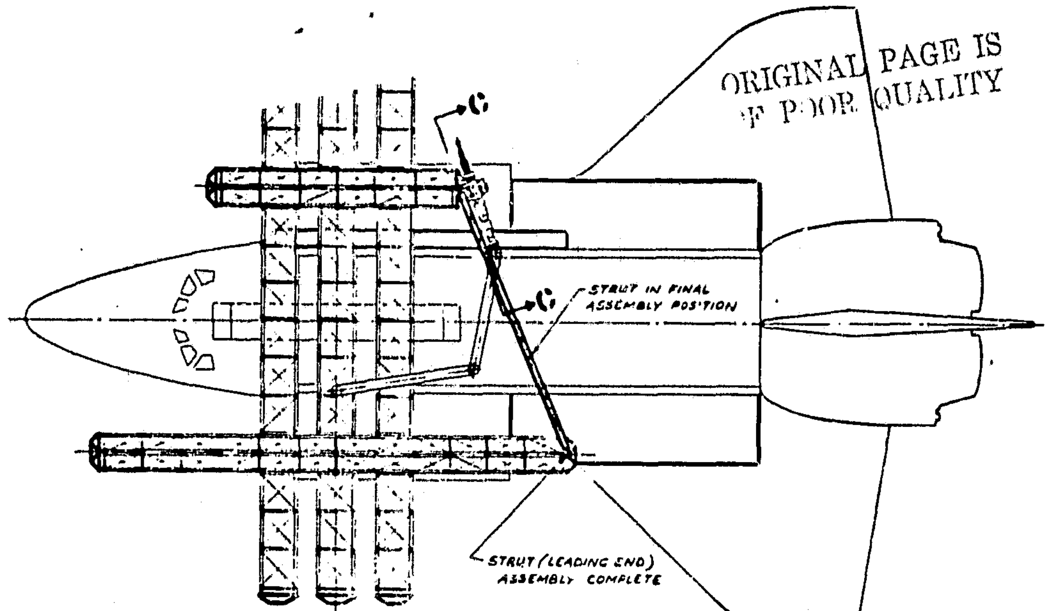
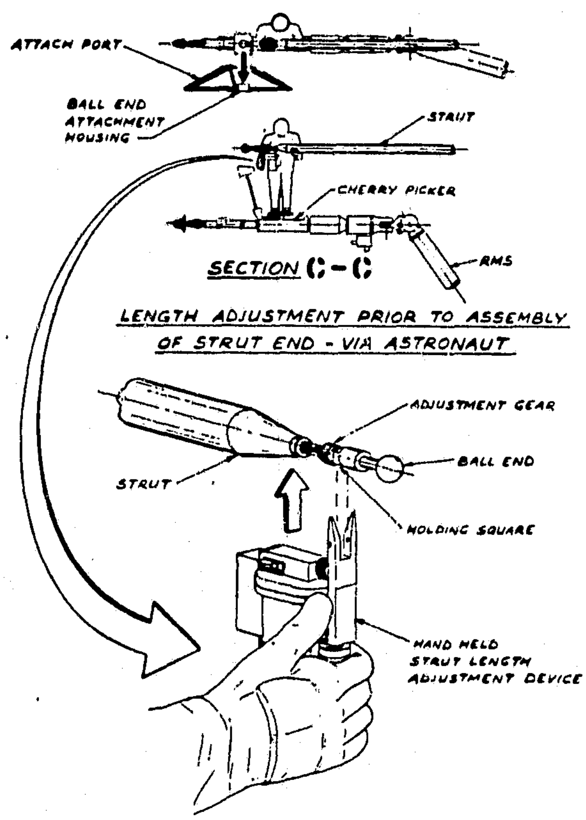


FIG. 5



STRUT (TRAILING END) ASSEMBLY PROCEEDURE VIA ASTRONAUT

FIG. 6

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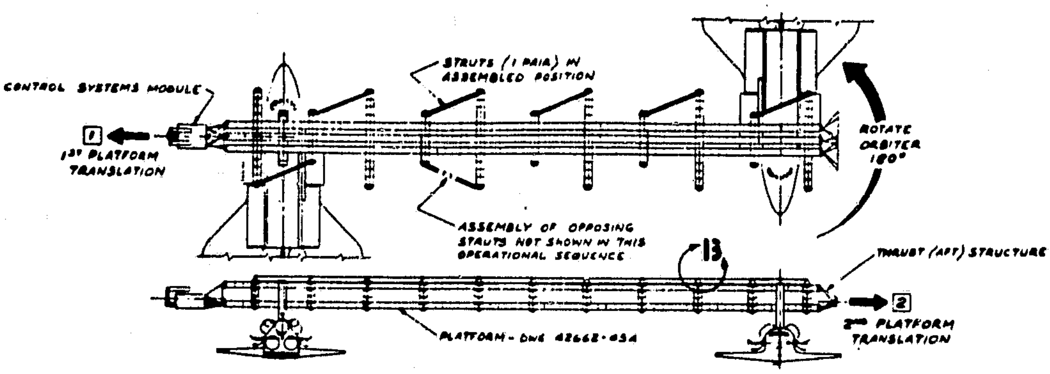
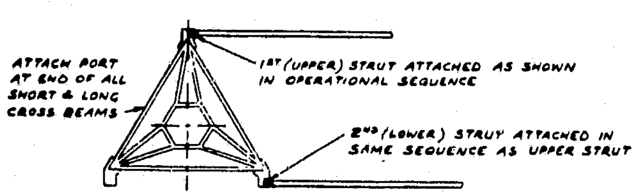
		DWG. NO.

ATTACHMENT 4



RELATIONSHIP OF ORBITER TO PLATFORM FOR STRUT ATTACHMENT AS DEPICTED

FIG. 7



DETAIL B
ASSEMBLY OF STRUTS (1 PAIR)
TO ATTACH PORT (TYPICAL)

FIG. 8

FORM 994-B-1 REV 12-78

INSTALL BRACING STRUTS ON PORT SIDE OF PLATFORM

ATTACHMENT 4

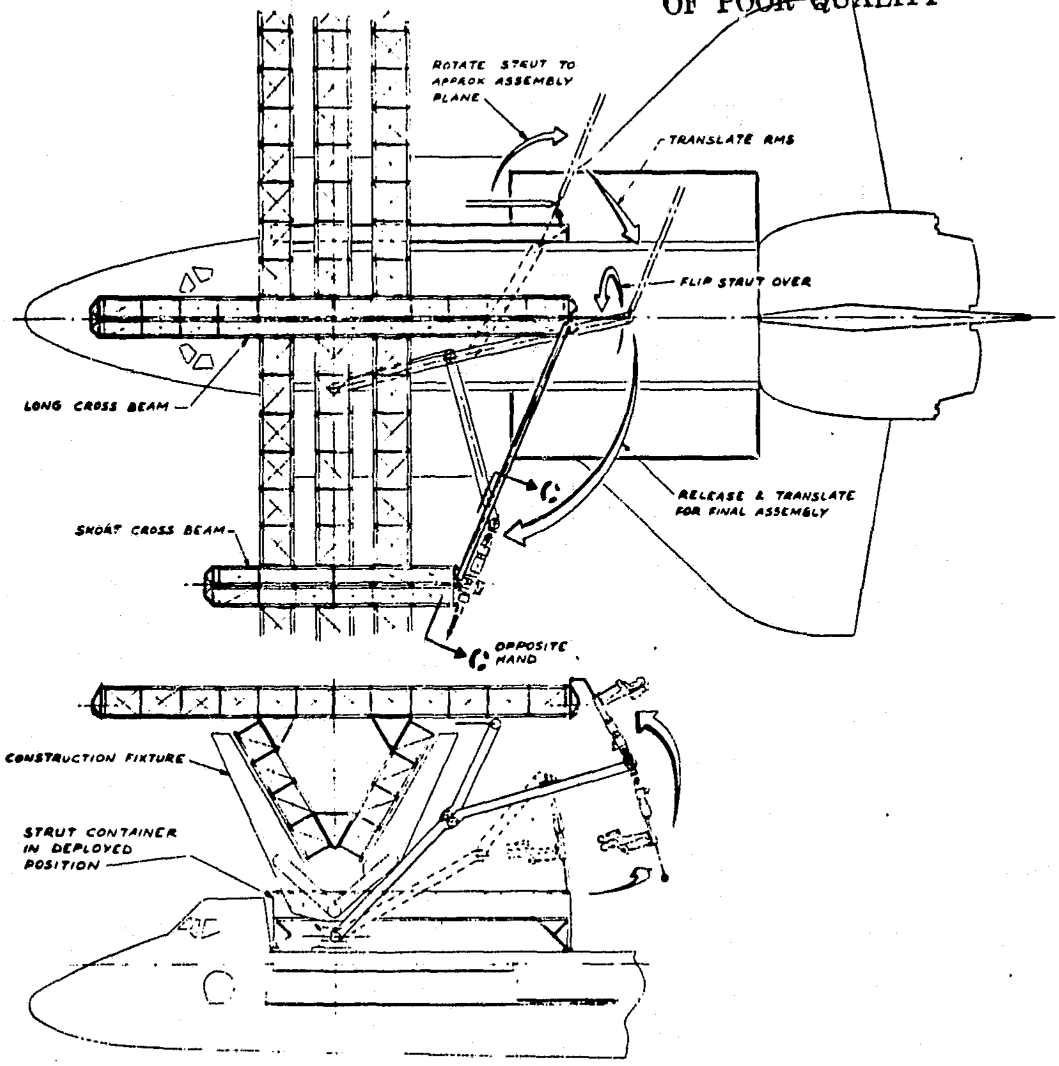
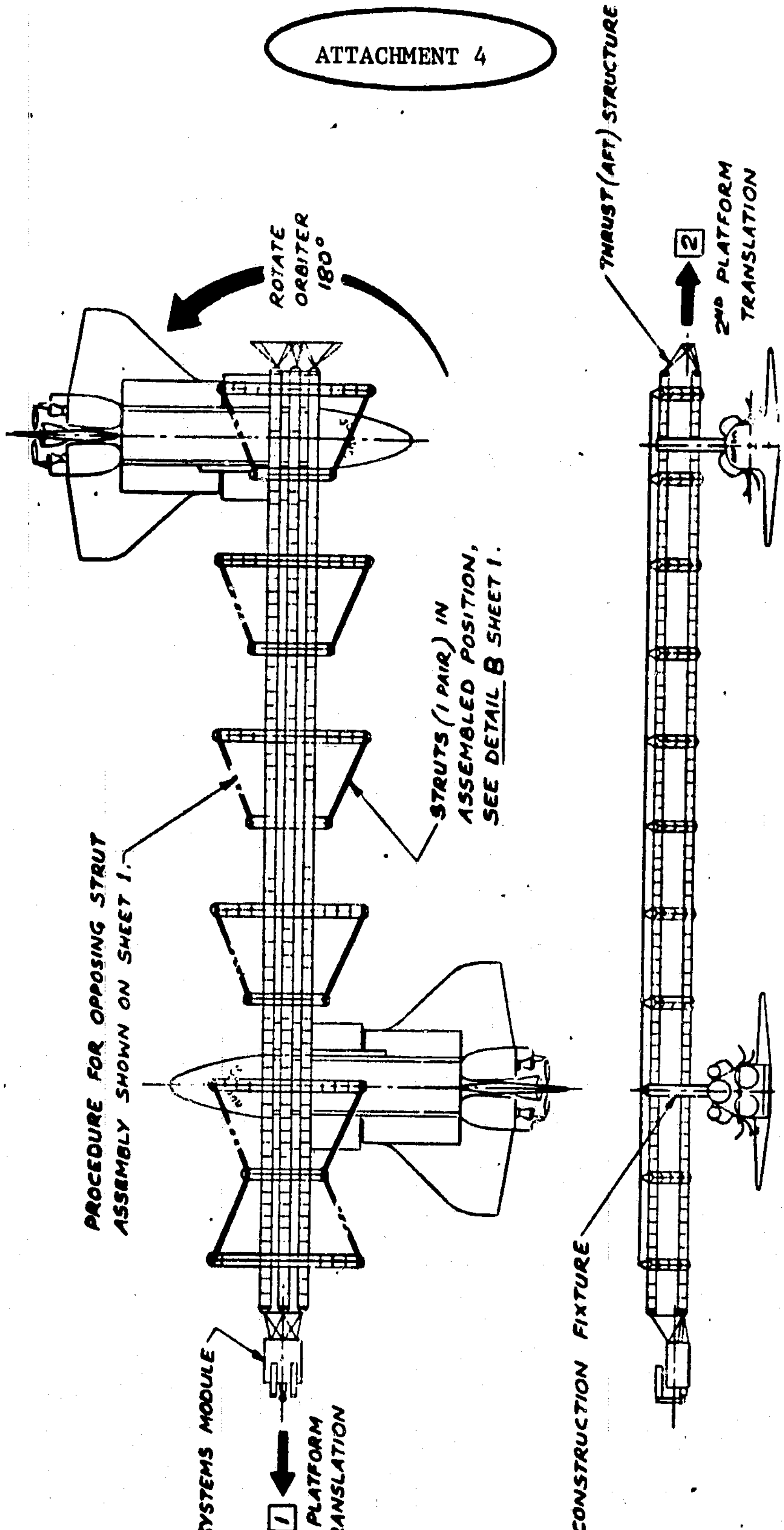


FIG. 9

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 8 OF 8
CHECKED BY:		ACTIVITY 25.0
DATE:	INSTALL BRACING STRUTS ON PORT SIDE OF PLATFORM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 4



RELATIONSHIP OF ORBITER TO PLATFORM FOR STRUT ATTACHMENT AS DEPICTED

NOTE: • PLATFORM IS TRANSLATED THRU CONSTRUCTION FIXTURE & ALL STRUTS A THRU C — ARE ASSEMBLED ON SIDE OF PLATFORM CLOSEST TO AFT END OF ORBITER:

• ORBITER IS ROTATED & PROCEDURE REPEATED.

FIG. 10

ACTIVITY 26.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

25.0 Install X-Beam Brace Struts on Port Side of Platform → 26.0 Rotate Platform 180° → 27.0 Install Thrust Structure

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

The platform is rotated 180 degrees about the axis of the berthing port on the construction fixture to bring the desired work areas within range of the RMS. A rotation mechanism has been included in the construction fixture mounting arrangement to accommodate this requirement.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system

TIMELINE

Rotation time = 60 minutes, based on an angular velocity of 3 degrees/minute

POWER/ENERGY

Peak power = average power = 0.1 kW for rotation; energy = 360 kJ

CREW LOAD

IVA astronaut—30 minutes, intermittently
EVA astronaut—not required

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Tri-beam construction fixture rotation system

ACTIVITY 27.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT Engineering and Technology Verification Platform (ETVP)

ACTIVITY

26.0 Rotate Orbiter 180° → **27.0 Install Thrust Structure** → 28.0 Install Wiring at Aft End of Platform

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-60, Interorbital Thrust Structure

DESCRIPTION OF ACTIVITY

This activity consists of removing three struts from the strut canister and installing them to join together the aft ends of the platform longitudinal beams, then removing the collapsed thrust structure (see Attachment 3) from the orbiter cargo bay, and installing and deploying it at the aft end of the platform. Specific steps in the installation operations are delineated in Attachment 1. Attachments 2, 3, and 4 illustrate the general features.

CONSTRUCTION SUPPORT EQUIPMENT

RMS, cherry picker, lighting, and hook tool

TIMELINE

4 hours, 56 minutes, 30 seconds (see Attachment 1)

POWER/ENERGY

Peak power, 2.145 kW; average power, 1.384 kW, energy, 24,613 kJ (see Attachment 1)

CREW LOAD

EVA—One man, continuously

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ACTIVITY 27.0

ATTACHMENT 1

TIME, POWER, AND ENERGY ESTIMATION FOR INSTALLATION OF THE INTERORBITAL ENGINE THRUST STRUCTURE

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MOVE THE EVA ASTRONAUT IN THE CHERRY PICKER ON THE RMS TO THE STRUT CONTAINER.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
2. GRASP STRUT NO. 10 WITH THE CHERRY PICKER STABILIZER AND REMOVE IT FROM THE CONTAINER.		0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
3. MOVE THE CHERRY PICKER TO THE AFT END OF THE PLATFORM AT THE APEX LONGITUDINAL.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
4. USING THE STABILIZER, INSTALL THE BALL END OF THE STRUT INTO THE BALL SOCKET OF THE ATTACH PORT ON THE APEX LONGITUDINAL. THE BALL WILL AUTOMATICALLY LOCK INTO THE SOCKET WHEN IT IS INSERTED.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
5. RELEASE THE STABILIZER FROM THE STRUT, MOVE THE CHERRY PICKER TO THE OTHER END OF THE STRUT & GRASP IT WITH THE STABILIZER.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
6. USING THE STABILIZER, INSTALL THE BALL END OF THE STRUT INTO THE BALL SOCKET OF THE ATTACH PORT OF THE LONGITUDINAL. THE BALL WILL AUTOMATICALLY LOCK INTO THE SOCKET WHEN IT IS INSERTED. RELEASE THE STABILIZER.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
7. INSTALL STRUT NO. 11 USING A PROCEDURE SIMILAR TO STEPS 1-6.	1800	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	1521 945 450
8. INSTALL STRUT NO. 12 USING A PROCEDURE SIMILAR TO STEPS 1-6.	1800	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	1521 945 450

SEE NOTES ON SHEET 5 OF 5

ATTACHMENT 1

ACTIVITY 27.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
9. MOVE THE EVA ASTRONAUT IN THE CHERRY PICKER ON THE RMS TO THE STOWED THRUST STRUCTURE IN THE ORBITER BAY. USE THE CHERRY PICKER STABILIZER TO GRASP THE THRUST STRUCTURE AT CENTRAL FRAME NO. 8.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
10. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE MECHANICAL LATCHES WHICH SECURE THE THRUST STRUCTURE TO ITS CRADLE.	30	0.02 (f) 1.050 (b) 0.250 (c)	0.02 (f) 0.525 (b) 0.250 (c)	6 16 8
11. USING THE RMS, TRANSPORT THE THRUST STRUCTURE TO THE VICINITY OF ITS INSTALLED LOCATION AT THE AFT END OF THE APEX LONGITUDINAL OF THE PLATFORM.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
12. INSTALL THE BALL JOINT AT THE END OF CENTRAL FRAME NO. 8 (THRUST STRUCTURE) INTO THE SOCKET ON THE END ATTACH PORT AT THE AFT END OF THE APEX LONGITUDINAL. THE BALL WILL AUTOMATICALLY LOCK INTO THE SOCKET WHEN IT IS INSERTED.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 1.050 (b) 0.250 (c)	253.5 157.5 75
13. USE THE CHERRY PICKER STABILIZER TO ROTATE THE THRUST STRUCTURE (STILL IN ITS UNDEPLOYED CONFIGURATION) ABOUT THE APEX BALL JOINT TO AN ATTITUDE SUCH THAT CENTRAL FRAME NO. 7 CAN BE DEPLOYED WITHOUT DANGER OF COLLISION.	120	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	101.4 63 30
14. UNCLIP THE HOOK TOOL FROM ITS STOWED POSITION ON THE CHERRY PICKER AND USE IT TO MANUALLY PULL ON THE LANYARD WHICH RELEASES THE LATCH SECURING CENTRAL FRAME NO. 7. THIS FRAME WILL NOW SLOWLY DEPLOY, POWERED BY SPRINGS AND RATE CONTROLLED BY A DAMPER, UNTIL IT REACHES ITS DESIGNATED ANGLE RELATIVE TO THE REMAINDER OF THE THRUST STRUCTURE. RESTOW THE HOOK TOOL.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75

ATTACHMENT 1

ACTIVITY 27.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
15. WAIT UNTIL THE QUASI-DEPLOYED STRUCTURE IS QUIESCENT AND RELEASE THE CHERRY PICKER STABILIZER FROM CENTRAL FRAME NO. 8. MOVE THE CHERRY PICKER TOWARD THE BALL JOINT AT THE END OF CENTRAL FRAME NO. 7, AND ATTACH THE STABILIZER TO THE GRASP POINT LOCATED NEAR THAT BALL JOINT.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
16. INSTALL THE BALL JOINT AT THE END OF CENTRAL FRAME NO. 7 (THRUST STRUCTURE) INTO THE SOCKET ON THE END ATTACH PORT AT THE AFT END OF THE LONGITUDINAL. THE BALL WILL AUTOMATICALLY LOCK INTO THE SOCKET WHEN IT IS INSERTED.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
17. INSTALL AND DEPLOY CENTRAL FRAME NO. 9 IN SIMILAR FASHION TO SETPS 13, 14, 15, AND 16. AT THE CONCLUSION OF STEP 17, THE CHERRY PICKER REMAINS ANCHORED TO CENTRAL FRAME NO. 9, CLOSE TO THE BALL JOINT.	1320	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	1115.4 693 330
18. UNCLIP THE HOOK TOOL FROM ITS STOWED POSITION ON THE CHERRY PICKER AND USE IT TO MANUALLY PULL ON THE LANYARD WHICH RELEASES THE LATCH SECURING THE NO. 2 OUTBOARD ENGINE TRUSS TO CENTRAL FRAME NO. 9. THE OUTBOARD ENGINE TRUSS WILL NOW SLOWLY DEPLOY, POWERED BY SPRINGS AND RATE CONTROLLED BY A DAMPER, UNTIL IT REACHES ITS DESIGNATED ANGLE RELATIVE TO THE REMAINDER OF THE THRUST STRUCTURE. RESTOW THE HOOK TOOL.	300	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	157.5 75
19. RELEASE THE CHERRY PICKER STABILIZER. MOVE THE CHERRY PICKER TO THE OPPOSITE END OF CENTRAL FRAME NO. 9. USE THE STABILIZER TO ANCHOR THE CHERRY PICKER TO CENTRAL FRAME NO. 9 SO THAT THE BALL SOCKET OF STRUT NO. 6 IS WITHIN REACH OF THE ASTRONAUT.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150

ACTIVITY 27.0

ATTACHMENT 1

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
20. UNCLIP THE HOOK TOOL FROM ITS STOWED POSITION ON THE CHERRY PICKER AND US IT TO MANUALLY PULL ON THE LANYARD WHICH RELEASES THE LATCH SECURING STRUT NO. 6 TO THE NO. 2 OUTBOARD ENGINE TRUSS. RELEASE THE LANYARD, THEN HOOK INTO THE STRUT RINGS (AS SHOWN IN ATTACHMENT 3). REEL IN THE HOOK AND BRING THE FREE END OF THE STRUT WITHIN REACH OF THE ASTRONAUT. UNFASTEN THE HOOK TOOL FROM THE STRUT RING. STOW THE HOOK TOOL.	400	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	210 100
21. MANUALLY INSTALL THE FREE END OF STRUT NO. 6 INTO THE BALL SOCKET ON THE CENTER ENGINE ATTACH PORT. ADJUST THE STRUT LENGTH AS REQUIRED BY MANUALLY TURNING THE ADJUSTING SCREW.	120	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	63 30
22. RELEASE THE CHERRY PICKER STABILIZER. MOVE THE CHERRY PICKER TO THE END ATTACH PORT OF THE NO. 2 OUTBOARD ENGINE. USE THE STABILIZER TO ANCHOR IT THERE SO THAT THE BALL SOCKET OF STRUT NO. 2 IS WITHIN REACH OF THE ASTRONAUT.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
23. INSTALL NO. 2 STRUT SIMILAR TO STEPS 20 AND 21.	520	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	273 130
24. INSTALL NO. 5 STRUT SIMILAR TO STEPS 22, 20, AND 21. AT THE CONCLUSION OF STEP 24, THE CHERRY PICKER IS LOCATED AT THE END ATTACH PORT OF NO. 2 OUTBOARD ENGINE.	600 520	0.845 (a) 1.050 (b) 0.250 (c) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c) 0.525 (b) 0.250 (c)	507 315 150 273 130
25. MOVE THE CHERRY PICKER TO CENTRAL FRAME NO. 9 AND ANCHOR IT.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150

ATTACHMENT 1

ACTIVITY 27.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
26. REPEAT STEPS 18 THROUGH 24 TO INSTALL NO. 1 OUTBOARD ENGINE AND NO. 3, 1, & 4 STRUTS. AT THE CONCLUSION OF STEP 26, THE CHERRY PICKER IS LOCATED AT THE END ATTACH PORT OF NO. 1 OUTBOARD ENGINE.	3660	2.145	1.190	4357.5
27. RELEASE THE CHERRY PICKER STABILIZER AND MOVE THE CHERRY PICKER AWAY FROM THE THRUST STRUCTURE.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
SUMMARY	17,790 (4 HOURS, 56 MINUTES, 30 SEC)	2.145 (d)	1.384 (e)	24,613.2

NOTES

(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER

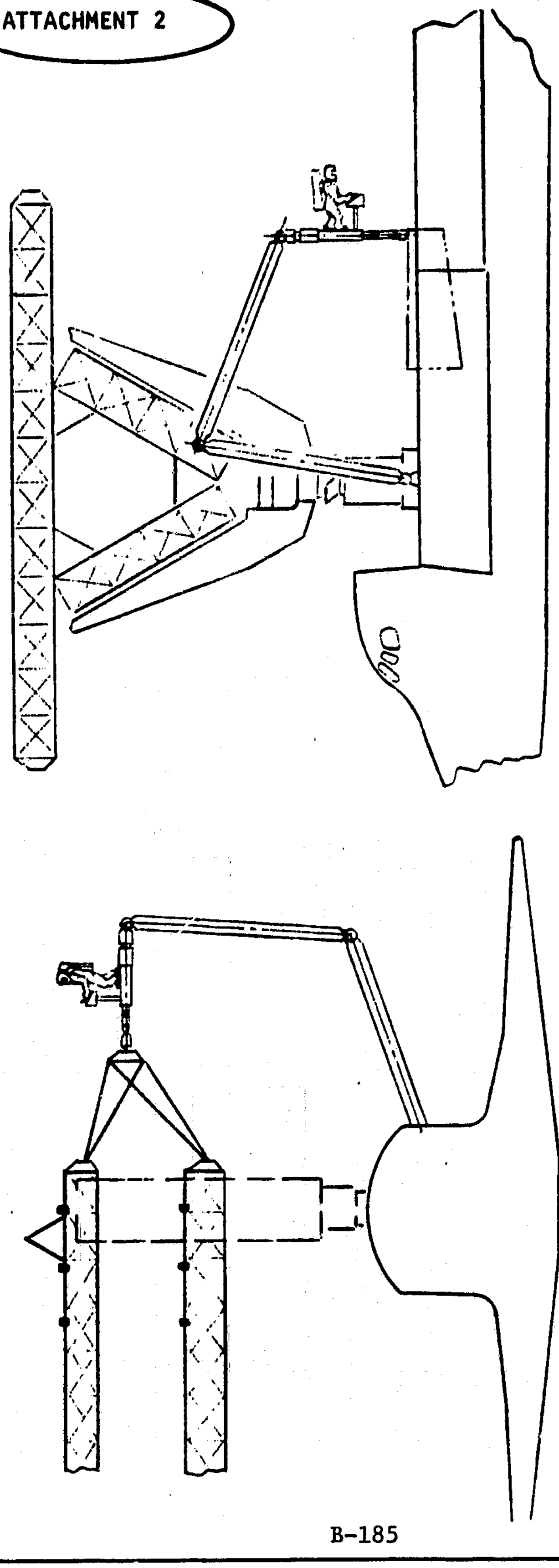
(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) LATCH

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 27.0
DATE:	INSTALL THRUST STRUCTURE	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2

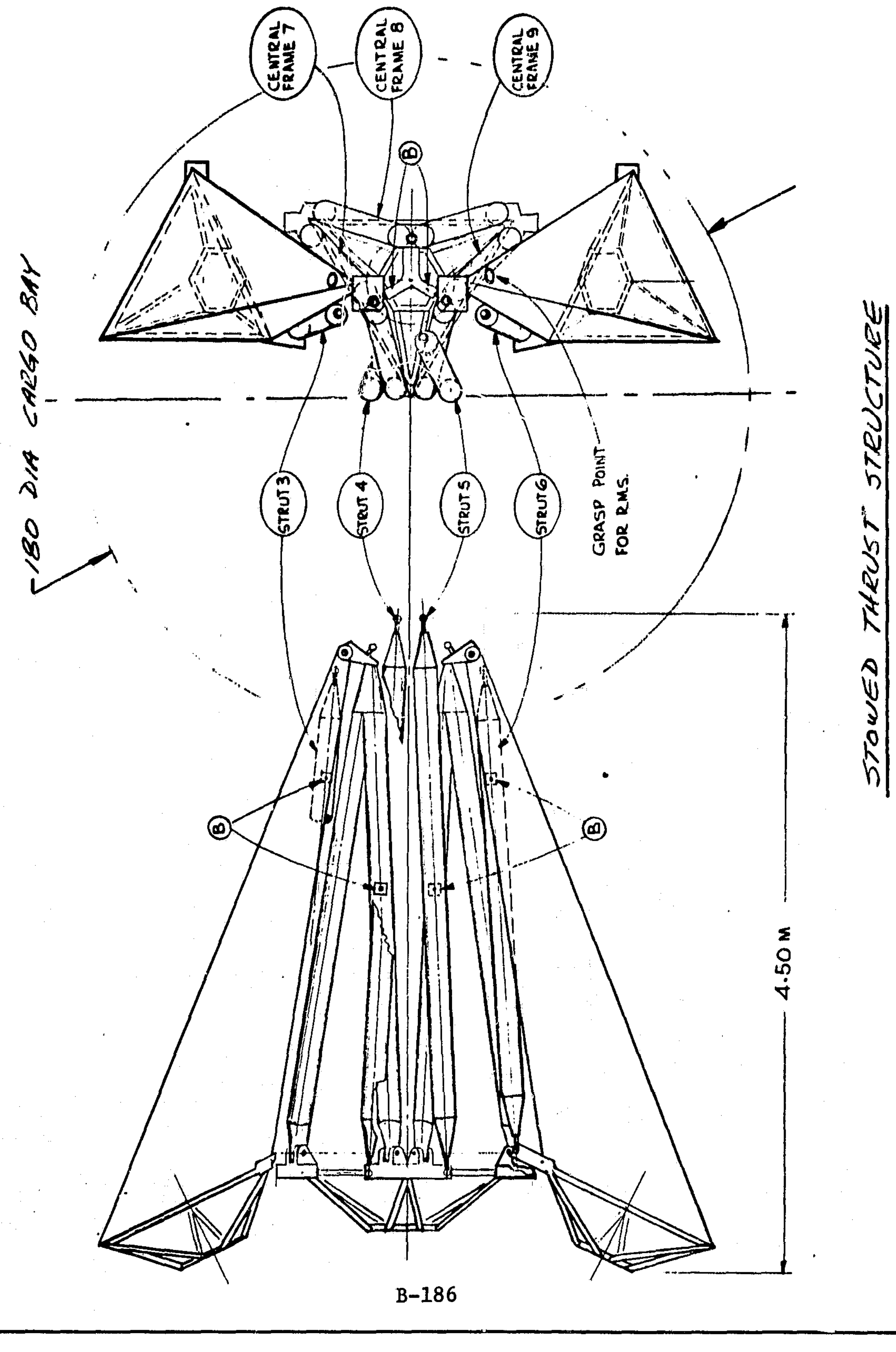


INSTALLING THE THRUST STRUCTURE

FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 27.0
DATE:	INSTALL THRUST STRUCTURE	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 3



FORM 994-B-1 REV 12-78

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 27.0
DATE:	INSTALL THRUST STRUCTURE	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 4

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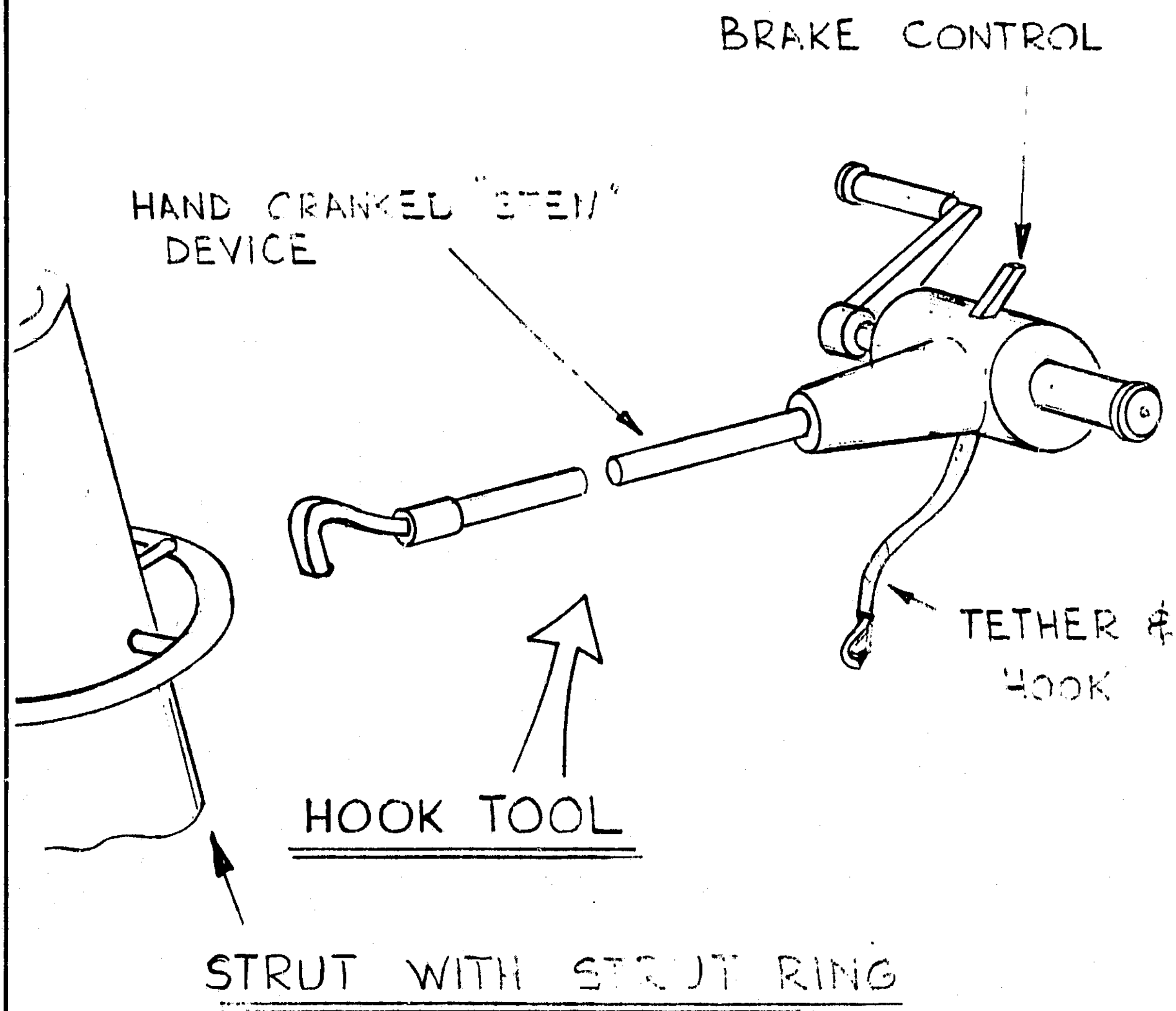

FORM 994-B-1 REV 12-78

Activity 28.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT Engineering and Technology Verification Platform (ETVP)

ACTIVITY

27.0 Install Thrust Structure → 28.0 Install Wiring at Aft End of Platform → 29.0 Install Antenna and Connect Wiring

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-73, Special Lines and Antenna Installation, Aft End

DESCRIPTION OF ACTIVITY

The activity consists of removing the wiring package from the bracing strut container and then installing it at the aft end of the platform. Specific steps in the activity are delineated in Attachment 1. Attachments 2 and 3 illustrate details relating to the wiring installation.

CONSTRUCTION SUPPORT EQUIPMENT

RMS, cherry picker, and lighting

TIMELINE: 49 minutes (see Attachment 1)

POWER/ENERGY

Peak power, 2.145 kW; average power, 1.292 kW; energy, 3800 kJ (see Attachment 1)

CREW LOAD

EVA: One man continuously

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

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ACTIVITY 28.0

ATTACHMENT 1

TIME, POWER, AND ENERGY ESTIMATION FOR INSTALLATION OF WIRING AT THE AFT END OF THE PLATFORM

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MOVE THE EVA ASTRONAUT IN THE CHERRY PICKER ON THE RMS TO THE WIRING PACKAGE WHICH IS STOWED IN THE BRACING STRUT CONTAINER. GRASP THE PACKAGE WITH THE CHERRY PICKER STABILIZER.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
2. USING THE RMS, TRANSPORT THE WIRING PACKAGE TO THE REAR END OF THE PLATFORM. LOCATE THE CHERRY PICKER SO THAT THE BEAM CROSSMEMBER TO WHICH THE WIRING IS TO BE INSTALLED IS WITHIN REACH OF THE ASTRONAUT.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
3. ROTATE THE STABILIZER HOLDING THE WIRING PACKAGE SO THAT THE WIRING PACKAGE IS WITHIN REACH OF THE ASTRONAUT.	120	0.250 (c) 1.050 (b)	0.250 (c) 0.525 (b)	30 63
4. MANUALLY REMOVE THE WIRING PACKAGE FROM THE STABILIZER AND SECURE IT TO THE BEAM CROSSMEMBER WITH THE ATTACHED STRAPS. THE FAR END OF THE WIRING PACKAGE WILL BE LOCATED ON (BUT NOT ATTACHED TO) THE CROSSMEMBER ON THE APEX BEAM.	300	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	157.5 75
5. MANUALLY CONNECT THE PIGTAILED CONNECTOR OF THE WIRING PACKAGE TO THE EXISTING CONNECTOR ON THE PLATFORM LONGITUDINAL BEAM.	300	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	157.5 75
6. MOVE THE CHERRY PICKER TO THE APEX BEAM, AND LOCATE IT IN A CONVENIENT POSITION FOR INSTALLING THE WIRING PACKAGE.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.120 (c)	507 315 150
7. MANUALLY INSTALL THE WIRING PACKAGE TO THE CROSS-MEMBER OF THE APEX BEAM USING THE ATTACHED STRAPS.	120	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	157.5 75
8. MANUALLY CONNECT THE PIGTAILED CONNECTOR OF THE WIRING PACKAGE TO THE EXISTING CONNECTOR WHICH IS PART OF THE ELECTRICAL HARNESS OF THE APEX BEAM END ATTACH PORT.	120	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	63 30

ACTIVITY 28.0

ATTACHMENT 1

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
SUMMARY	2940 (49 MIN.)	2.145 (d)	1.292 (e)	3799.5

NOTES

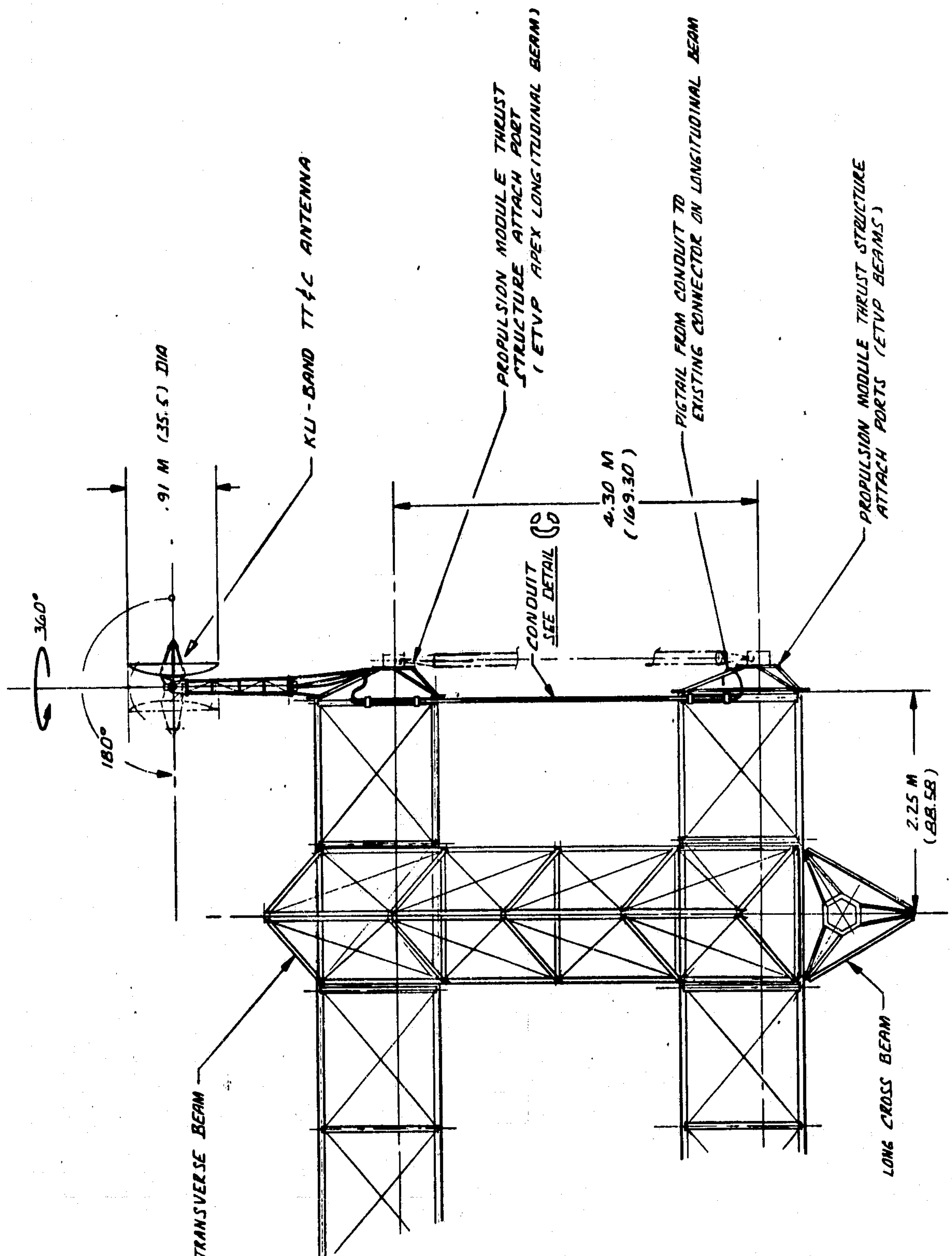
(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER

(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 2
CHECKED BY:		ACTIVITY 28.0
DATE:	INSTALL WIRING AT AFT END OF PLATFORM	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2



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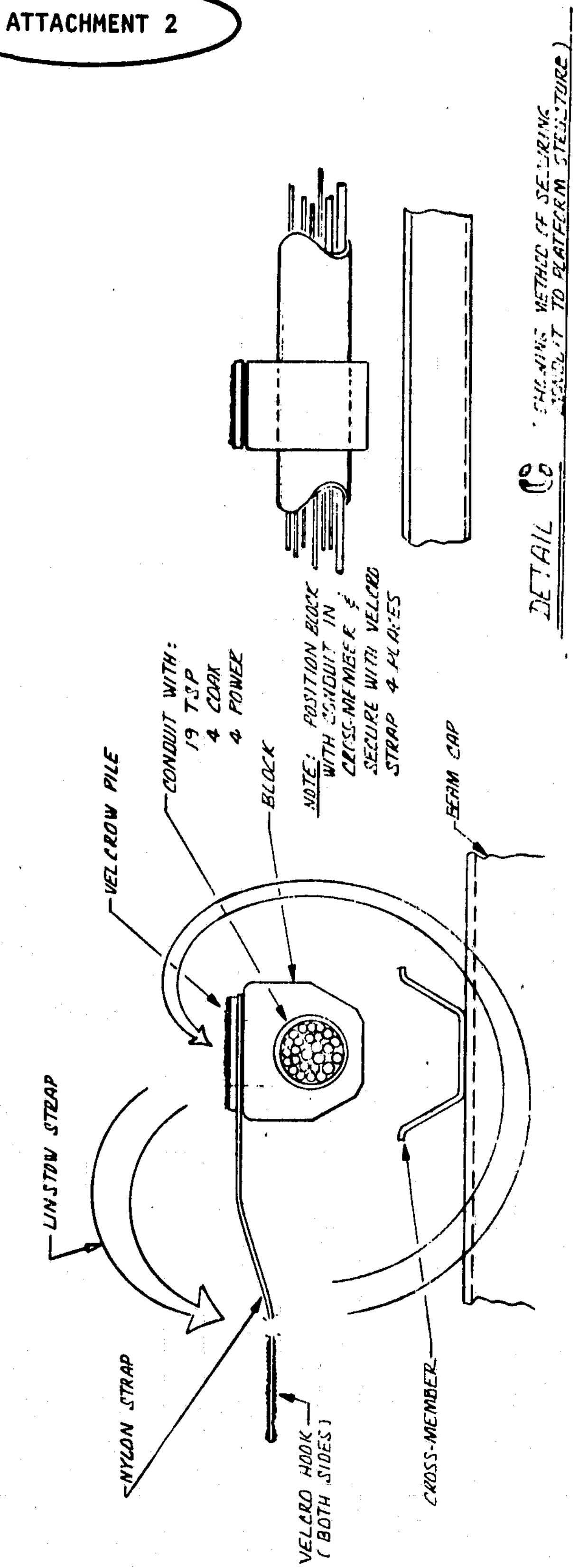
CHECKED BY:		ACTIVITY 28.0
DATE:	INSTALL WIRING AT AFT END OF PLATFORM	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 2



FORM 994-B-1 REV 12-78

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CHECKED BY:		ACTIVITY 28.0
DATE:	INSTALL WIRING AT AFT END OF PLATFORM	MODEL NO. ETVP
REF.		DWG. NO.

ATTACHMENT 3

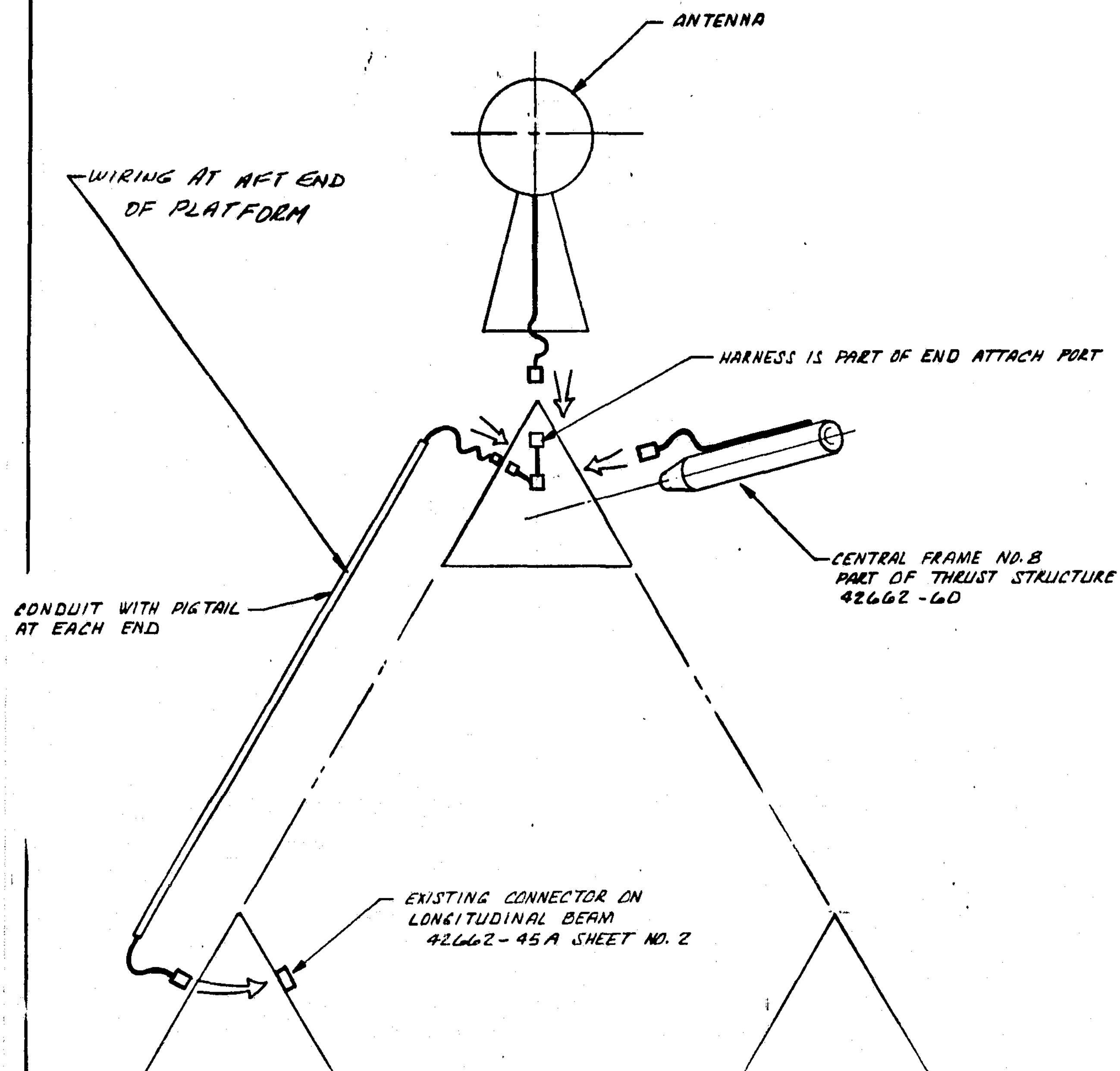

DIAGRAM OF ELECTRICAL CONNECTIONS

ACTIVITY 29.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT Engineering and Technology Verification Platform (ETVP)

ACTIVITY

28.0 Install Wiring at Aft End of Platform	→ 29.0 Install and Connect TT&C antenna; Connect Thrust Structure Wiring to Platform Wiring	→ 30.0 Install X-Beam Brace Struts on Starboard Side

REFERENCE DATA

1. Space Construction Data Base
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-73, Special Lines and Antenna Installation, Aft End

DESCRIPTION OF ACTIVITY

The activity consists of removing the antenna from the orbiter cargo bay, installing and connecting it, and then electrically connecting the wiring on the thrust structure to the platform wiring. Specific steps in this activity process are delineated in Attachment 1. Attachments 2 and 3 illustrate major component features.

CONSTRUCTION SUPPORT EQUIPMENT

RMS, cherry picker, and lighting

TIMELINE

42 minutes (see Attachment 1)

POWER/ENERGY (see Attachment 1)

Average power, 1.473 kW; peak power, 2.145 kW; total energy, 3711 kJ

CREW LOAD

One man continuously—EVA

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ATTACHMENT 1

SHEET 1 OF 2

TIME, POWER, AND ENERGY ESTIMATION FOR INSTALLATION OF TT&C ANTENNA AND FOR ELECTRICALLY CONNECTING THE THRUST STRUCTURE (29.0)

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MOVE THE CHERRY PICKER TO THE LOCATION OF THE Ku-BAND ANTENNA STOWED IN THE ORBITER BAY; GRASP THE ANTENNA WITH THE STABILIZER ARM OF THE CHERRY PICKER.	600	0.845 (a) 1.050 (b) 0.500 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
2. BY REMOTE CONTROL FROM THE ORBITER CREW CABIN, RELEASE THE ELECTROMECHANICAL LATCH(ES) WHICH RETAIN THE ANTENNA IN ITS STOWED LOCATION.	30	0.02 (f) 1.050 (b) 0.250 (c)	0.02 (f) 0.525 (b) 0.250 (c)	6 16 8
3. TRANSPORT THE ANTENNA TO ITS INSTALLED LOCATION AT THE AFT END OF THE APEX LONGITUDINAL BEAM.	30	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
4. USING THE STABILIZER ARM, INSTALL THE ANTENNA TO ITS INTERFACE; THE SECURING LATCH WILL AUTOMATICALLY LOCK THE ANTENNA WHEN IT IS CORRECTLY CLOSED.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
5. MANUALLY CONNECT THE PIGTAILED CONNECTOR (PART OF THE ANTENNA HARNESS) TO THE HARNESS OF THE APEX BEAM END ATTACH PORT.	120	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	63 30
6. MANUALLY UNFASTEN THE VELCRO STRAP WHICH SECURES THE PIGTAILED CONNECTOR ON CENTRAL FRAM NO. 8; THIS IS PART OF THE ELECTRICAL HARNESS OF THE INTERORBITAL ENGINE THRUST STRUCTURE.	120	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	63 30
7. MANUALLY CONNECT THE PIGTAILED CONNECTOR (FROM STEP 9) TO THE HARNESS OF THE APEX BEAM END ATTACH PORT.	120	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	63 30
8. MOVE CHERRY PICKER AWAY FROM THE AFT END OF THE PLATFORM.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
SUMMARY	2520 (42 MIN.)	2.145 (d)	1.473 (e)	3711

SEE NOTES ON SHEET 2

ACTIVITY 29.0

ATTACHMENT 1

SHEET 2 OF

NOTES

(a) BASIC RMS

(b) RMS HEATER

(c) CHERRY PICKER

(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) LATCH

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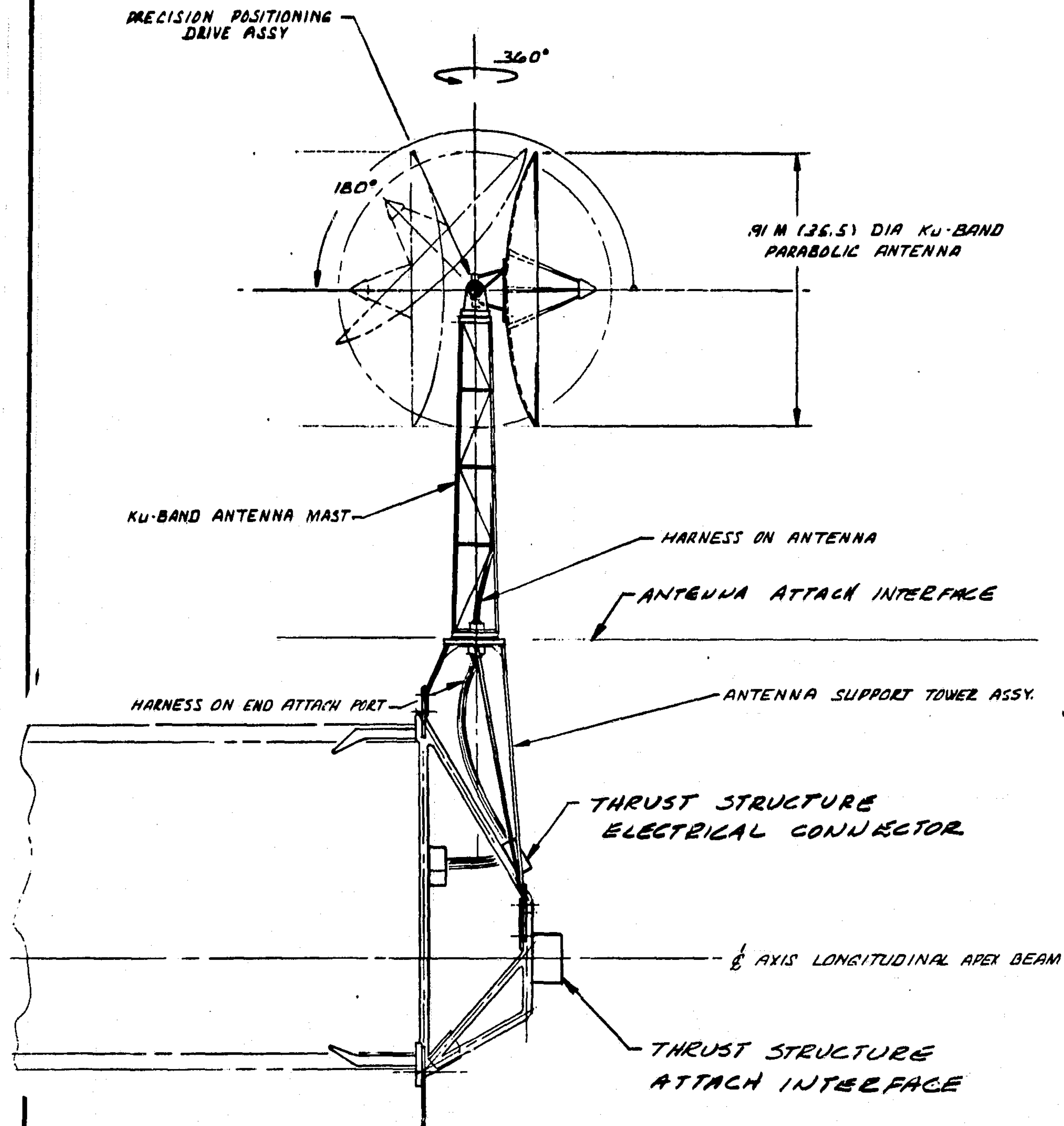
CHECKED BY:		ACTIVITY 29.0
DATE:	INSTALL & CONNECT TT&C ANTENNA & CONNECT THRUST STRUCTURE WIRING TO PLATFORM WIRING	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



TT&C ANTENNA

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DATE:	INSTALL & CONNECT TT&C ANTENNA; CONNECT THRUST STRUCTURE WIRING TO PLATFORM WIRING	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3

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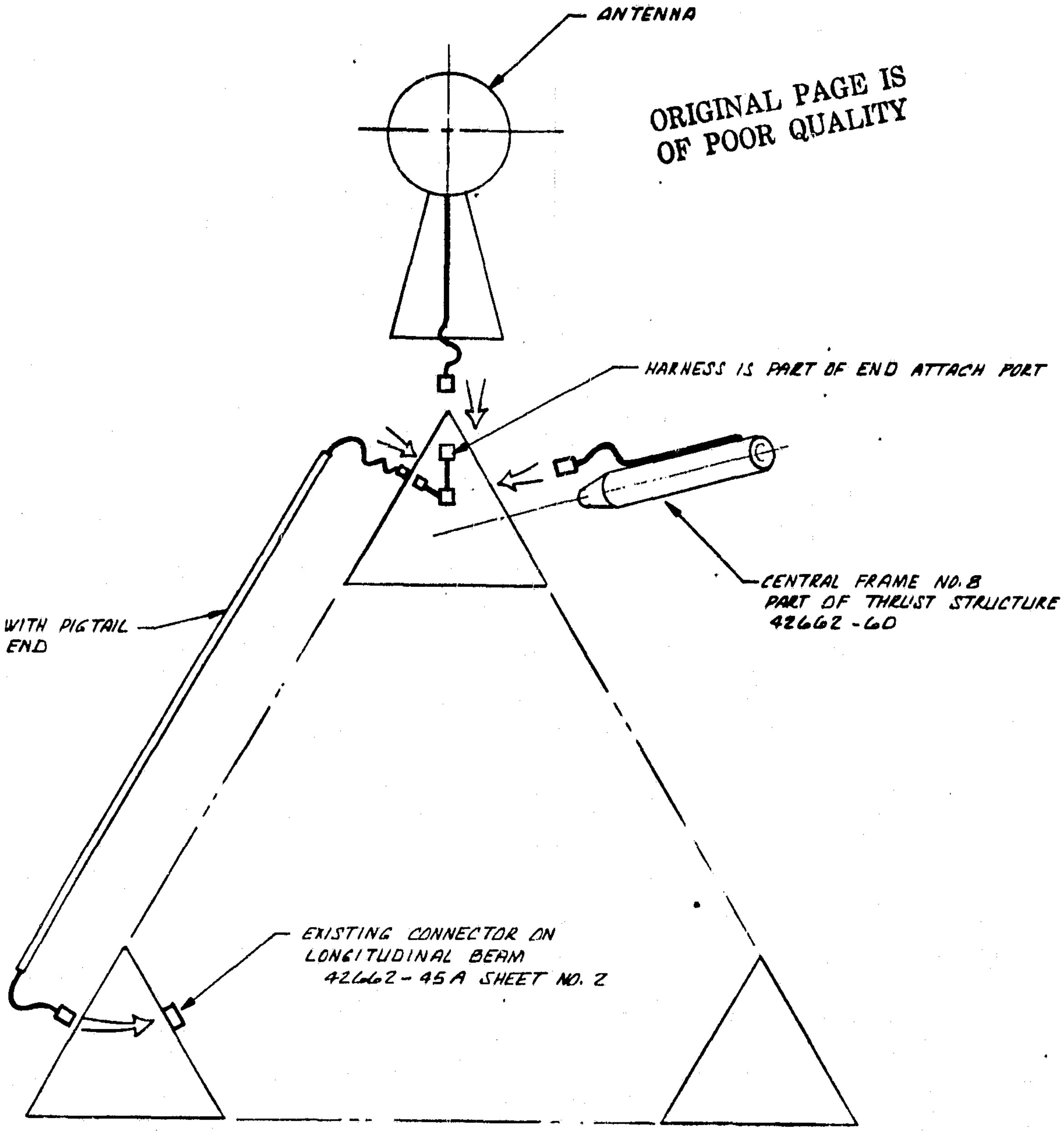

DIAGRAM OF ELECTRICAL CONNECTIONS

FORM 994-B-1 REV 12-78

ACTIVITY 30.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

29.0 Install and Connect TTC Antenna, Connect Thrust Structure Electrical into Special Wiring	→	30.0 Install Bracing Struts on Starboard Side	→	31.0 Rotate Platform 180 Degrees

REFERENCE DATA

1. Drawing 42662-45, Tri-Beam Concept, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Drawing 42662-71, Bracing Strut Installation via Cherry Picker

DESCRIPTION OF ACTIVITY

This activity is the same as Activity 25.0, except that the bracing struts will be installed on the opposite side of the platform.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system
3. RMS with astronaut cherry picker
4. Bracing strut stowage canister

TIMELINE: 10 hours, 58 minutes (see Attachment 2, Activity 25.0)

POWER/ENERGY (see Attachment 2, Activity 25.0)

Peak power, 2.992 kW—occurs during most of the task; average power, 2.236 kW; energy, 88,260 kJ

CREW LOAD

EVA astronaut—10 hours, 58 minutes (continuous)
IVA astronaut—10 hours, 58 minutes (monitoring and support activities)

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Tri-beam construction fixture system
2. RMS with astronaut cherry picker
3. Bracing strut stowage canister

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Activity 31.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

30.0 Install Bracing Struts on Starboard Side → 31.0 Rotate Platform 180° → 32.0 Distribution System Checks

NOTE: THIS ACTIVITY IS IDENTICAL TO 26.0. SEE THAT ACTIVITY DATA PACKAGE FOR DETAILS.

ACTIVITY 32.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

31.0 Rotate 180°	→	32.0 Distribution System Check and Partial Functional Check	→	33.0 Remove Cherry Picker

REFERENCE DATA

1. Engineering and Technology Verification Platform (ETVP) Definition
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-67, Shuttle Bay Packaging, Ground Flight Platform
4. Drawing 42662-74, Solar Array Assembly
5. Space Construction Data Base

DESCRIPTION OF ACTIVITY

By means of the cherry picker, an electrical cable from a spring-loaded reel in the orbiter bay is connected to a receptacle on the control module. This cable is used also for ground checkout of the ETVP systems and it is wired accordingly. The solar array system is unfolded and rotated, but not extended. The continuity of all of the connections made in space is verified; also, the latches and motorized electrical connectors located at the crossbeam ends and at the thrust structure ports are functionally checked. Subsequent to this verification of the electrical distribution system, the electrical cable from the control module (CM) to the orbiter is disconnected and stowed on the spring-loaded reel in the payload bay. Attachment 1 delineates the steps in the operation; Attachments 2 and 3 illustrate the operations.

TIMELINE: 1 hour, 55 minutes, 30 seconds (see Attachment 1)

POWER/ENERGY

Peak power, 2.145 kW; average power, 1.148 kW; energy, 7958 kJ (see Attachment 1)

CREW LOAD

One man (EVA), continuous, RMS/cherry picker
One man (IVA), one hour, 7-1/2 minutes, 50% time—monitoring, checkout

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

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ACTIVITY 32.0

ATTACHMENT 1

TIME, POWER, AND ENERGY ESTIMATION FOR ELECTRICAL DISTRIBUTION CHECK

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MOVE THE EVA ASTRONAUT ON THE RMS/CHERRY PICKER TO THE CHECKOUT CABLE REEL IN THE PAYLOAD BAY.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
2. GRASP THE CONNECTOR END OF THE CABLE WITH THE STABILIZER ARM OF THE CHERRY PICKER.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
3. MOVE THE EVA ASTRONAUT ON THE RMS/CHERRY PICKER TO THE CONTROL MOD. THE CABLE WILL PAY OUT FROM THE SPRING-LOADED REEL WITH SUFFICIENT TENSION TO KEEP THE CABLE UNDER CONTROL.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
4. MATE THE CONNECTOR AT THE END OF THE CABLE TO THE RECEPTACLE IN THE CONTROL MOD. THE CONNECTOR/RECEPTACLE WILL LATCH AUTOMATICALLY WHEN IT IS MATED.	300	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	157.5 75
5. THE RMS/CHERRY PICKER REMAINS AT THIS LOCATION WHILE THE CHECKOUT IS PERFORMED (STEPS 6 THROUGH 16). Note: The control module can now be commanded from the orbiter crew cabin. All checkout operations are initiated from this location.	(4050)	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	2126.3 1012.5
6. RELEASE THE LATCHES (2) WHICH TIE DOWN THE SOLAR PANELS IN THEIR STOWED POSITION.	30	0.04 (f)	0.4 (f)	1.2
7. ROTATE ONE SOLAR PANEL ASSY (HALF WING) 180°, STARBOARD SIDE.	180	0.10 (g)	0.10 (g)	18.0
8. REPEAT STEP 7 FOR PORT SIDE.	180	0.10 (g)	0.10 (g)	18.0
9. UNFOLD WING HINGE 90°, STARBOARD SIDE.	90	0.10 (g)	0.10 (g)	9.0
10. REPEAT STEP 9 FOR PORT SIDE.	90	0.10 (g)	0.10 (g)	9.0
11. EXTEND TELESCOPING MAST FOR STARBOARD SIDE.	90	0.10 (g)	0.10 (g)	9.0
12. REPEAT STEP 11 FOR PORT SIDE.	90	0.10 (g)	0.10 (g)	9.0

0.85

SEE NOTES ON SHEET 3.

ACTIVITY 32.0

ATTACHMENT 1

SHEET 2 OF 3

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
13. ROTATE THE ROTARY JOINT BETWEEN THE CM AND THE SOLAR ARRAY ASSEMBLY: 5 MIN. @ LEO RATE, 1 REV/93 MIN; 5 MIN. @ GEO RATE, 1 REV/24 HOURS; 6 MIN @ 1/2 REV/SEC, 360 DEGREES. ALSO, NOD THE SOLAR ARRAYS THROUGH ±40° CONCURRENT WITH STEPS 14 AND 15.	(1320)	0.20 (g)	0.20 (g)	264
14. VERIFY CONTINUITY OF THE ELECTRICAL DISTRIBUTION SYSTEM TO EACH OF THE 15 ATTACH PORTS.	900	0.1 (g)	0.1 (g)	90
15. FUNCTION, OPEN/CLOSE EACH OF THE THREE LATCHES AT EACH OF THE 15 ATTACH PORTS.	1200	0.06 (f)	0.06 (f)	72
16. FUNCTION, EXTEND/RETRACT THE MOTORIZED ELECTRICAL CONNECTORS AT EACH OF THE 15 ATTACH PORTS.	1200	0.05 (g)	0.05 (g)	60
17. THE EVA ASTRONAUT ON THE RMS/CHERRY PICKER MANUALLY UNLATCHES THE CABLE BETWEEN THE ORBITER BAY & THE CONTROL MODULE BY USING THE HOOK TOOL WHICH IS STOWED ON THE CHERRY PICKER.	180	1.050 (b) 0.250 (c)	0.525 (b) 0.250 (c)	94.5 45
18. MOVE THE EVA ASTRONAUT ON THE RMS/CHERRY PICKER TO THE CABLE REEL IN THE BAY. THE SPRING ON THE CABLE REEL WILL RESTOW THE CABLE.	600	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	507 315 150
19. RELEASE THE CONNECTOR END OF THE CABLE FROM THE GRASP OF THE CHERRY PICKER STABILIZER & MOVE THE RMS/CHERRY PICKER AWAY FROM THE BAY.	300	0.845 (a) 1.050 (b) 0.250 (c)	0.845 (a) 0.525 (b) 0.250 (c)	253.5 157.5 75
SUMMARY	6930 (1 HOUR, 55 MINUTES, 30 SECONDS)	2.145 (d)	1.142 (e)	7913

ATTACHMENT 1

SHEET 3 OF 3

ACTIVITY 32.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
NOTES (a) BASIC RMS (b) RMS HEATER (c) CHERRY PICKER (d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY. (e) AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$ (f) LATCHES (g) PLATFORM MECHANISMS AND CIRCUITS				

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CHECKED BY:		ACTIVITY 32.0
DATE:	DISTRIBUTION SYSTEM CHECK AND PARTIAL FUNCTIONAL CHECK	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

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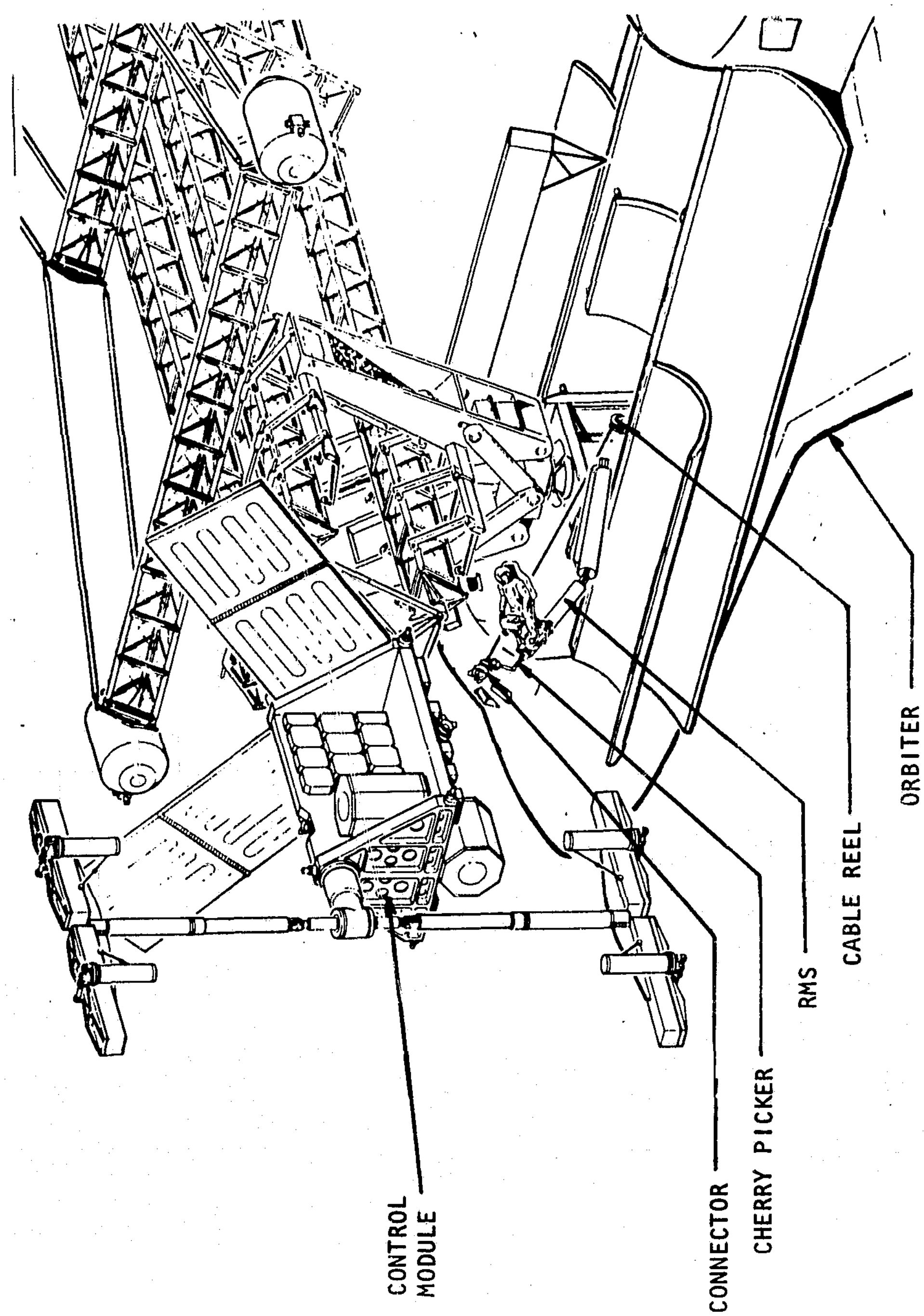

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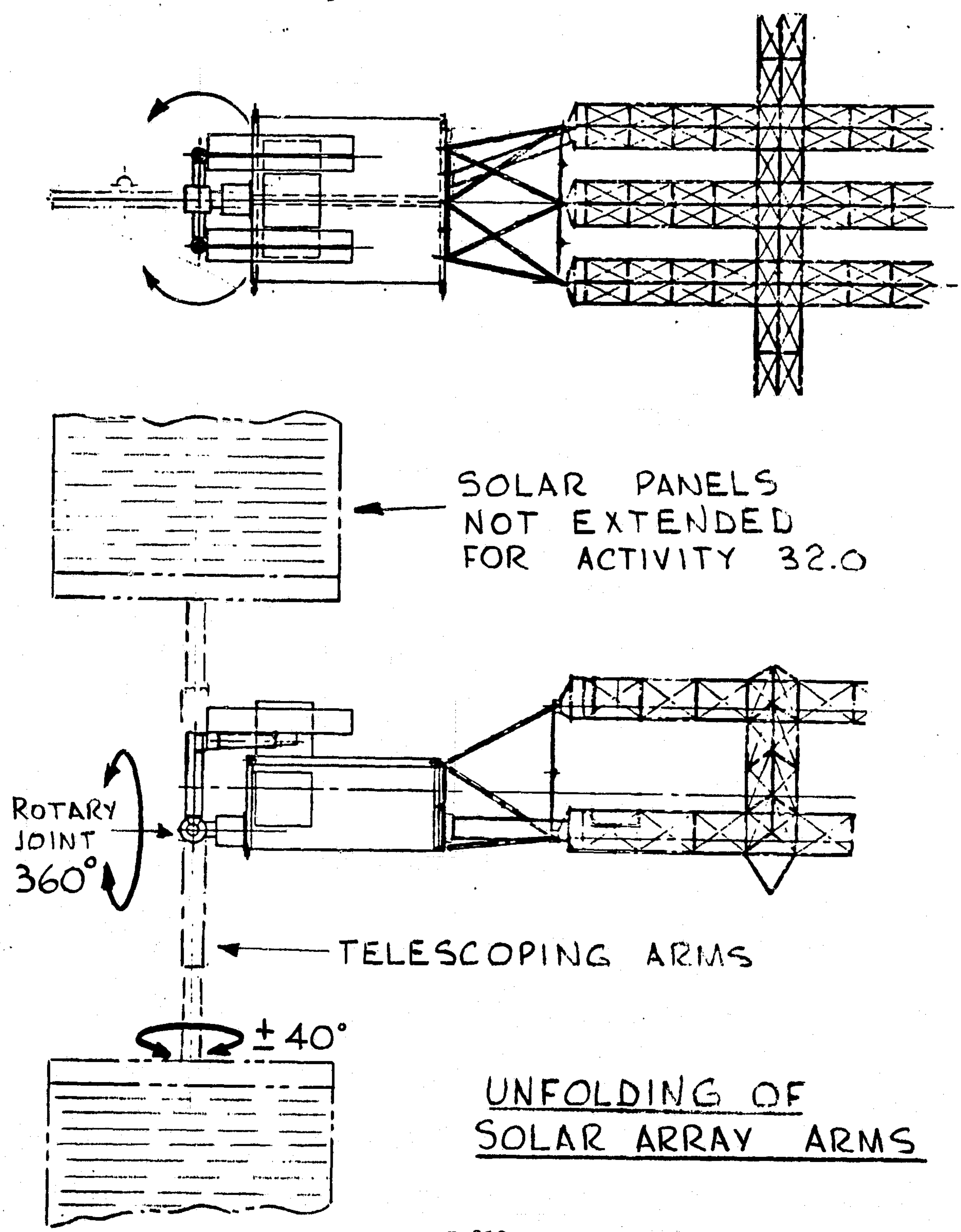
CHECKED BY:		ACTIVITY 32.0
DATE:	DISTRIBUTION SYSTEM CHECK AND PARTIAL FUNCTIONAL CHECK	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



UNFOLDING OF SOLAR ARRAY ARMS

FORM 994-B-1 REV 12-78

ACTIVITY 33.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

32.0 Distribution System Check → 33.0 Remove Cherry Picker → 34.0 Prepare Alignment Instrumentation

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP

2. Space Construction Data Base

3. Figure 8, p. A-15, Manned Remote Work Station Development Article: Final Report—Volume I, Book 1, Flight Article Requirements; and Appendix A, Mission Requirements. Report NSS-MR-RP008, Grumman Aerospace Corporation, March 1, 1979

DESCRIPTION OF ACTIVITY

The cherry picker is not required for the remainder of this mission. Therefore, at this time, it is returned to the orbiter storage location where the EVA operator dismounts to a foot support device and folds the cherry picker for stowage. By control from the crew cabin, the RMS then stows it in the orbiter cargo bay, ready for the return flight, while the EVA operator ingresses through the airlock to the crew cabin.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Light and TV system
3. RMS with astronaut cherry picker and end effectors

TIMELINE

20 minutes

POWER/ENERGY

Peak power, 2.992 kW; average power, 2.454 kW; energy, 2945 kJ

CREW LOAD

IVA—20 minutes, continuous; EVA—20 minutes, continuous

TECHNOLOGY DEVELOPMENT REQUIREMENTS

RMS astronaut cherry picker and end effector system

ACTIVITY 34.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

33.0 Remove Cherry Picker	→	34.0 Prepare Alignment Measurement Instrumentation	→	35.0 Install Alignment IMU on Control Module

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

By remote control from the crew cabin, the two IMU's are prepared for installation on the control module (CM) and the platform crossbeam attach ports for determining relative alignment. See Attachments 1, 2, and 3 for details.

TIMELINE

8 hours (see Attachment 1)

POWER/ENERGY

Virtually none; the IMU's are battery powered after initial spinup of gyros by orbiter power.

CREW LOAD

One man, IVA

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Develop the subsystem boxes which contain the three-axis IMU's, recording equipment, time base, and batteries.

ATTACHMENT 1

From overall operational considerations, the requirement exists to be able to point the payloads (such as antennas) to specific target areas. The ability to point to a desired target area involves several factors. The pointing of the basic tri-beam platform is accomplished by the precision attitude reference package which incorporates star trackers and gyros. The payloads are mounted on the ends of the crossbeams by the previously discussed male and female attach port systems. Therefore, it is necessary to determine the relative alignment between the precision attitude reference package on the control module and each crossbeam attach port. The attachment of each payload to its female attach port can be adjusted and aligned on the ground before carrying to orbit and subsequent berthing to the tri-beam platform. This technique will provide a known alignment relationship between the payload and the precision attitude reference package.

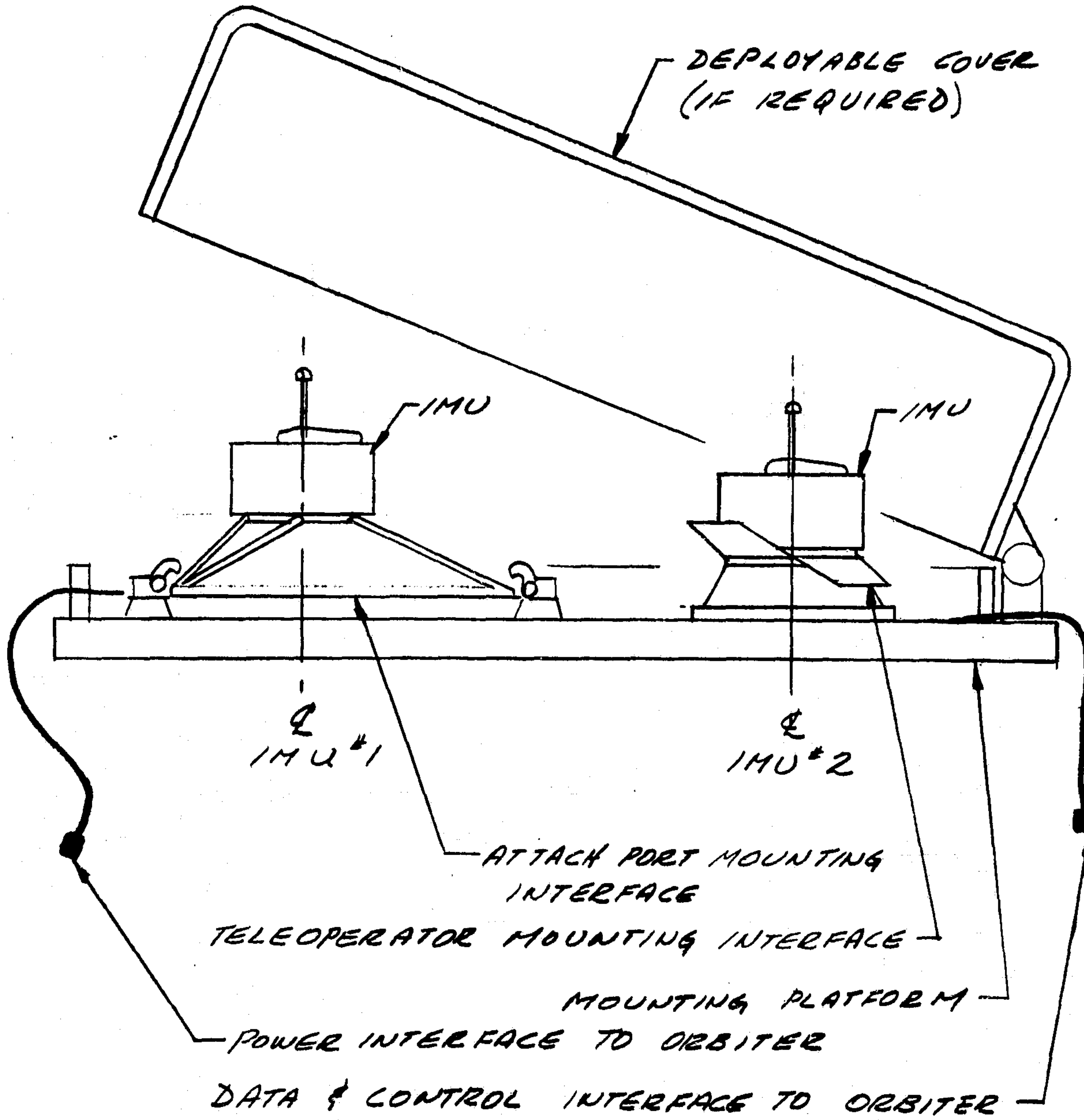
Determination of the relative alignment, in three orthogonal axes, between the precision attitude reference package and each crossbeam attach port is accomplished by the use of two inertial measurement units (IMU's). One IMU is attached to the control module, and the other IMU is sequentially attached to each crossbeam attach port. The relative alignment is measured between each attach port and the control module and recorded to provide the data base for ground adjustment of the payload female attach port system.

The two IMU's are platform-mounted on a cradle for transport to orbit as part of the second flight payload. Attachment 2 illustrates the arrangement of the IMU's on the mounting platform. A deployable cover will be provided, if required, for environmental reasons. Prior to removal of the IMU's from the platform, power is supplied and the internal gyros are spun up.

The timeline requirements are based on the premise that the alignment measurement period should be preceded by a calibration period for both IMU's, while on the stable platform. This calibration time should be of equal duration to that required for the total alignment measurement period, which is approximately six hours. An additional hour is allocated for spinup of the IMU gyros, so that this activity starts seven hours prior to Activity 35.0. In addition, a post-measurement calibration period of one hour is provided (also considered part of Activity 34.0) following the actual measurements, thus making a total of eight hours. All of this activity time is conducted in parallel with other construction activity, and thus adds nothing to elapsed time on orbit.

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 34.0
DATE:	PREPARE ALIGNMENT MEASUREMENT INSTRUMENTATION	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



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ATTACHMENT 3

	Weight (lb)
Sensor unit	26
Electronics control unit	22
Recorder or memory with timeline	5
Silver-zinc battery	35
Total	88 lb (40 kg)

Weight of sensor and electronic control is based on Bendix permanent magnet rate ingegrating gyroscope (64 PM RIG). Power required = 75 W @ 28 VDC.

Time required for IMU alignment operation is approx. 6 hours (per Activity Sheets 34.0, 35.0, 36.0, 37.0 and 38.0).

A silver-zinc battery for 1400 watt-hours would require a volume and weight as indicated:

7 hours × 100 watts × factor of 2 = 1400 watt-hours.

Physical size of IMU is driven by size of mounting interfaces with RMS end effector and attach port/teleoperator berthing interfaces. Assume 23" W × 23" D × 11" H.

ACTIVITY 35.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

34.0 Prepare Alignment Instrumentation — 35.0 Install Alignment IMU on CM — 36.0 Perform Alignment of Attach Ports on Port Side

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

The cover of the baseline mounting fixture in the orbiter bay is opened, IMU No. 2 is grasped by the RMS, and then the latches securing the IMU are released by remote control. IMU No. 2 is transported by the RMS to the control module (CM) and installed on the teleoperator docking port located there. Latches on the teleoperator docking port are remotely activated by means of the TTC antenna to secure IMU No. 2.

TIMELINE: 32 minutes (see Attachment 1)

POWER/ENERGY

Peak power, 2.121 kW; average power, 1.701 kW; energy, 3266 kJ (see Attachment 1)

CREW LOAD

IVA—One man continuously, operating the RMS

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ACTIVITY 35.0

ATTACHMENT 1

TIME, POWER, AND ENERGY ESTIMATION FOR INSTALLING ALIGNMENT IMU ON CONTROL MODULE

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. BY REMOTE CONTROL FROM THE CREW CABIN, OPEN THE COVER OF THE BASELINE MOUNTING FIXTURE IN THE ORBITER BAY.	60	0.02	0.02	12
2. MOVE THE RMS TO THE BASELINE MOUNTING FIXTURE AND GRASP IMU NO. 2 ASSEMBLY.	600	0.845(a) 1.050(b)	0.845 0.525	507 315
3. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE LATCHES WHICH SECURE IMU NO. 2 ASSEMBLY.	30	0.02	0.02	6
4. USE THE RMS TO TRANSPORT IMU NO. 2 ASSEMBLY TO THE CONTROL MODULE AND POSITION IT AT THE TELEOPERATOR DOCKING PORT.	600	0.845(a) 1.050(b)	0.845 0.525	507 315
5. INSTALL THE IMU NO. 2 ASSEMBLY ONTO THE TELEOPERATOR DOCKING PORT.	300	0.845(a) 1.050(b)	0.845 0.525	253.5 157.5
6. BY REMOTE CONTROL FROM THE CREW CABIN AND VIA THE TT&C ANTENNA, ACTIVATE THE LATCHES ON THE TELEOPERATOR DOCKING PORT TO SECURE THE IMU NO. 2 ASSY.	30	0.02	0.02	6
7. RELEASE THE RMS & MOVE IT AWAY FROM THE CONTROL MODULE.	300	0.845(a) 1.050(b)	0.845 0.525	253.5 157.5
SUBTOTAL	1920 (32 MIN.)	1.915	1.297	2490
RMS LIGHTING	1920	0.173	0.173	332
TV & HEATER	1920	0.033	0.023	44
SUMMARY	1920	2.121(c)	1.701(d)	3266

NOTES (a) BASIC RMS; (b) RMS HEATER; (c) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY;

(d) AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

ACTIVITY 36.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

35.0 Install Alignment IMU on CM	→	36.0 Measure Alignment of Attach Ports on Port Side of Platform	→	26.0 (Repeat) Rotate 180 Degrees

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

An RMS grasps the IMU No. 2 assembly, remotely actuated latches release the IMU from its structural mounting in the orbiter cargo bay, and the RMS then translates it to a mounting position on the control module (CM). In a similar manner, IMU No. 1 is removed from the cargo bay and sequentially installed on the port side ends of the long crossbeam attach ports. A record is made of the data from both IMU's to provide the information for determining the relative alignment between each attach port and the CM. Attachment 1 delineates the steps in the operation. Attachments 2 and 3 illustrate the general features.

TIMELINE

2 hours, 18 minutes, 45 seconds (see Attachment 1) (see Section 5.3)

POWER/ENERGY

Peak power, 2.2 kW; average power, 1.3 kW; energy, 10,900 kJ
(see Attachment 1) (see Section 5.3)

CREW LOAD

IVA—one man continuously, operating the RMS

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

ACTIVITY 36.0

ATTACHMENT 1

TIME, POWER, AND ENERGY ESTIMATION FOR PERFORMING ALIGNMENT OF ATTACH PORTS ON PORT SIDE OF ETVP

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MOVE THE RMS TO THE BASELINE MOUNTING FIXTURE AND GRASP IMU NO. 1 ASSEMBLY.	600	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	507 315
2. BY REMOTE CONTROL FROM THE CREW CABIN, RELEASE THE LATCHES WHICH SECURE IMU NO. 1 ASSEMBLY.	30	0.02 (e) 1.050 (b)	0.02 (e) 0.525 (b)	0.6 16
3. USE THE RMS TO TRANSPORT IMU NO. 1 ASSEMBLY FROM THE BASELINE MOUNTING FIXTURE TO THE END OF THE FIRST CROSSBEAM ON THE PORT SIDE OF THE ETVP.	600	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	507 315
4. INSTALL IMU NO. 1 ASSEMBLY ONTO THE ATTACH PORT.	300	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	253.5 157.5
5. BY REMOTE CONTROL FROM THE CREW CABIN, AND VIA THE TTC ANTENNA, CLOSE THE LATCHES ON THE ATTACH PORT AND SECURE IMU NO. 1 ASSEMBLY.	30	0.02 (e) 1.050 (b)	0.02 (e) 0.525 (b)	0.6 16
6. RELEASE THE RMS & BACK IT AWAY A SHORT DISTANCE FROM THE IMU NO. 1 ASSEMBLY (TO ELIMINATE DISTORTION ON THE CROSSBEAM DURING ALIGNMENT MEASUREMENT).	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63
7. GRASP IMU NO. 1 ASSEMBLY WITH THE RMS.	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63
8. RELEASE THE ATTACH PORT LATCHES.	30	0.02 (e) 1.050 (b)	0.02 (e) 0.525 (b)	0.6 16
9. BACK THE RMS AND IMU NO. 1 ASSEMBLY A SAFE DISTANCE AWAY FROM THE ETVP.	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63
10. TRANSLATE THE ETVP THROUGH THE CONSTRUCTION FIXTURE A DISTANCE OF APPROXIMATELY 20 m @ 2.16 m/MIN, SO THAT THE NEXT CROSSBEAM IS LOCATED CONVENIENT TO THE RMS.	555	0.10 (f) 1.050 (b)	0.10 (f) 0.525 (b)	55.5 291
11 REPEAT STEPS 4,5,6,7,8,9, AND 10 FOUR TIMES.	5100 (4×1275)	1.915	1.007	5135.6 (4×1283.6)

ACTIVITY 36.0

ATTACHMENT 1

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
12. REPEAT STEPS 4 THROUGH 9 ONE TIME.	720	1.915	1.302	937.4
SUBTOTAL	8325 (2 HR, 18 MIN, 45 SEC)	1.915 (c)	1.084 (d)	9022.8
RMS LIGHTING	8325	0.173	0.173	1440.2
TV & HEATER (WRIST & ELBOW)	8325	0.070	0.057	474.5
SUMMARY	8325	2.158 (c)	1.314 (d)	10,937.5

NOTES

(a) BASIC RMS
(b) RMS HEATER
(c) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(d) AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(e) LATCH

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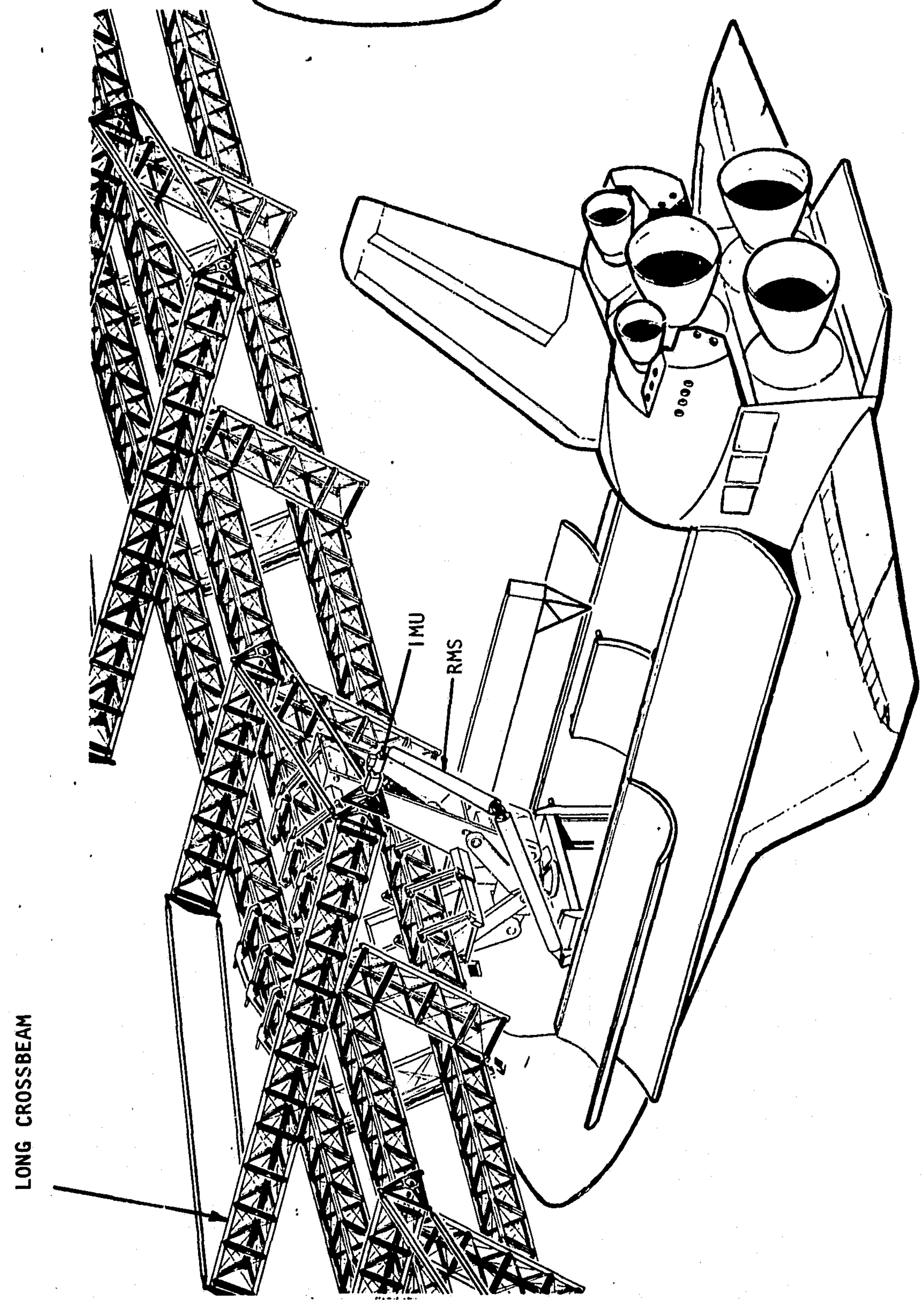
CHECKED BY:		ACTIVITY 36.0
DATE:	MEASURE ALIGNMENT OF ATTACH PORTS ON PORT SIDE OF PLATFORM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



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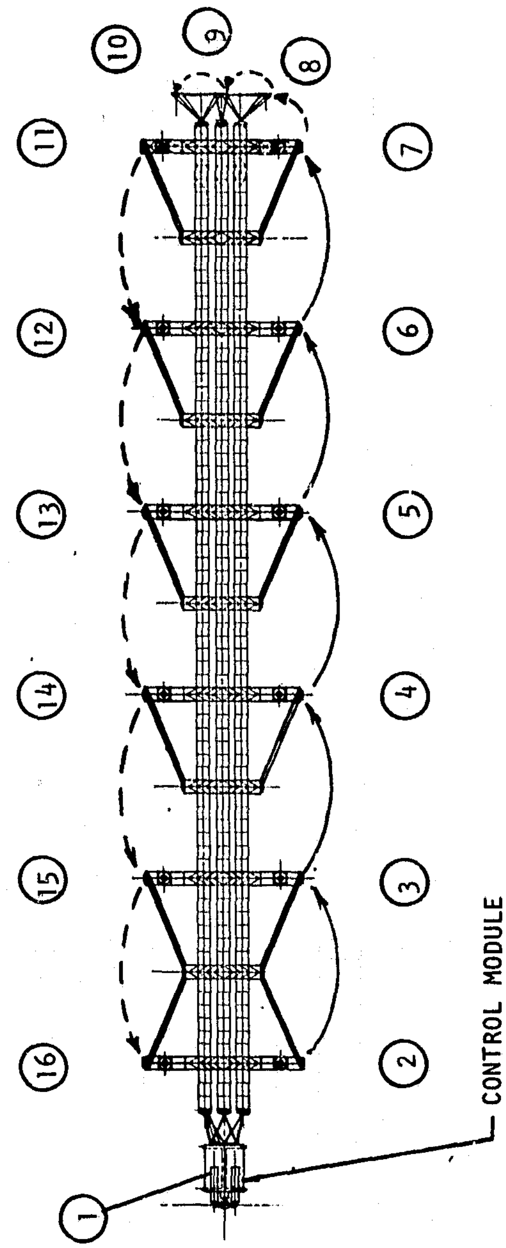
DATE:	MEASURE ALIGNMENT OF ATTACH PORTS ON PORT SIDE OF PLATFORM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



INSTALLATION SEQUENCE OF IMU's

POSITIONS 1 THROUGH 7 COVERED ON THIS ACTIVITY

FORM 994-B-1 REV 12-78

ACTIVITY 37.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

26.0 (Repeat) Rotate 180°	→	37.0 Measure Alignment of Attach Ports on Thrust Structure and along Starboard Side	→	38.0 Return Alignment IMU's to Orbiter

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

The activity consists of installing and removing the IMU No. 1 assembly to each of the three attach ports for the inter-orbital propulsion stages and then to the six attach ports along the starboard side of the ETVP. Attachment 1 delineates the operational steps; Attachment 2 illustrates IMU No. 1 attachment to a crossbeam. Attachment 3 shows platform positions.

TIMELINE

3 hours, 8 minutes, 15 seconds (see Attachment 1)(see Section 5.3)

POWER/ENERGY

Peak power, 2.2 kW; average power, 1.2 kW; energy, 14,100 kJ (see Attachment 1) (see Section 5.3)

CREW LOAD

One man (IVA) continuously, operating RMS.

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

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TIME, POWER, AND ENERGY ESTIMATION FOR PERFORMING ALIGNMENT OF ATTACH PORTS ON THRUST STRUCTURE AND ALONG STARBOARD SIDE OF ETVP

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. USE THE RMS TO TRANSPORT THE IMU NO. 1 ASSEMBLY TO THE FIRST ATTACH PORT OF THE THRUST STRUCTURE AND INSTALL IT.	900	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	760.5 472.5
2. BY REMOTE CONTROL FROM THE CREW CABIN AND VIA THE TTC ANTENNA, CLOSE THE LATCHES ON THE ATTACH PORT AND SECURE THE IMU NO. 1 ASSEMBLY.	30	0.02 (f) 1.050 (b)	0.02 (f) 0.525 (b)	0.6 16
3. RELEASE THE RMS AND BACK IT AWAY A SHORT DISTANCE FROM THE IMU NO. 1 ASSEMBLY (TO ELIMINATE DISTORTION ON THE IMU DURING ALIGNMENT MEASUREMENT)	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63
4. GRASP THE IMU NO. 1 ASSEMBLY WITH THE RMS.	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63
5. RELEASE THE ATTACH PORT LATCHES	30	0.02 (f) 1.050 (b)	0.02 (f) 0.525 (b)	0.6 16
6. REPEAT STEPS 1,2,3,4, AND 5 THREE TIMES. THIS COMPLETES THE ALIGNMENT MEASUREMENT OF THE THRUST STRUCTURE AND THE FIRST STARBOARD CROSSBEAM.	3600 (3 x 1200)	1.915	1.329	4785 (3 x 1595)
7. BACK THE RMS AND IMU NO. 1 ASSEMBLY A SAFE DISTANCE AWAY FROM THE ETVP.	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63
8. TRANSLATE THE ETVP THROUGH THE CONSTRUCTION FIXTURE A DISTANCE OF APPROXIMATELY 20 m @ 2.16 m/MIN. SO THAT THE SECOND CROSSBEAM IS CONVENIENT TO THE RMS.	555	0.10 (g)	0.10 (g)	55.5
9. INSTALL THE IMU NO. 1 ASSY ONTO THE ATTACH PORT.	300	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	253.5 157.5
10. REPEAT STEPS 2,3,4,5,7,8, & 9 FOUR TIMES	5100 (4 x 1275)	1.915	0.779	3971.6 (4 x 992.9)

SEE NOTES ON SHEET 2.

ATTACHMENT 1

ACTIVITY 37.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
11. REPEAT STEPS 2,3,4,5, & 7 ONE TIME	420	1.915	1.253	526.4
SUBTOTAL	11,295 (3 HOURS, 8 MINUTES, 15 SECONDS)	1.915 (d)	1.079 (e)	11,508.9
RMS LIGHTING	11,295	0.173	0.173	1954
TV & HEATER	11,295	0.70	0.57	643.8
SUMMARY	11,295	2.158	1.249	14,106.7

NOTES

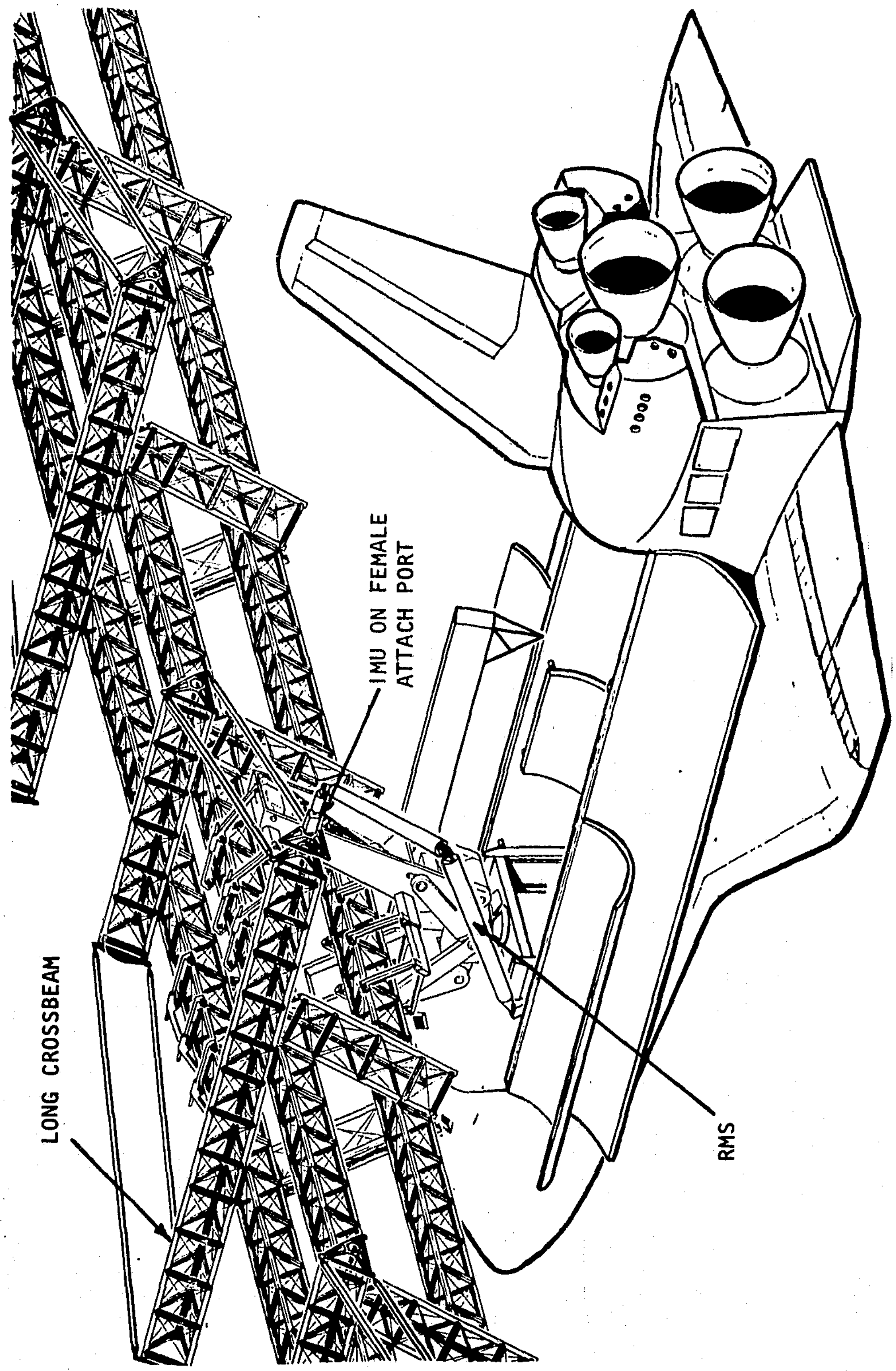
(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER
(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) LATCH
(g) CONSTRUCTION FIXTURE ROLLER DRIVES

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 37.0
DATE:	DETERMINE ALIGNMENT OF ATTACH PORTS ON THRUST STRUCTURE AND ALONG STARBOARD SIDE	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2



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DATE:	MEASURE ALIGNMENT OF ATTACH PORTS ON THRUST STRUCTURE & ALONG STARBOARD SIDE	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3

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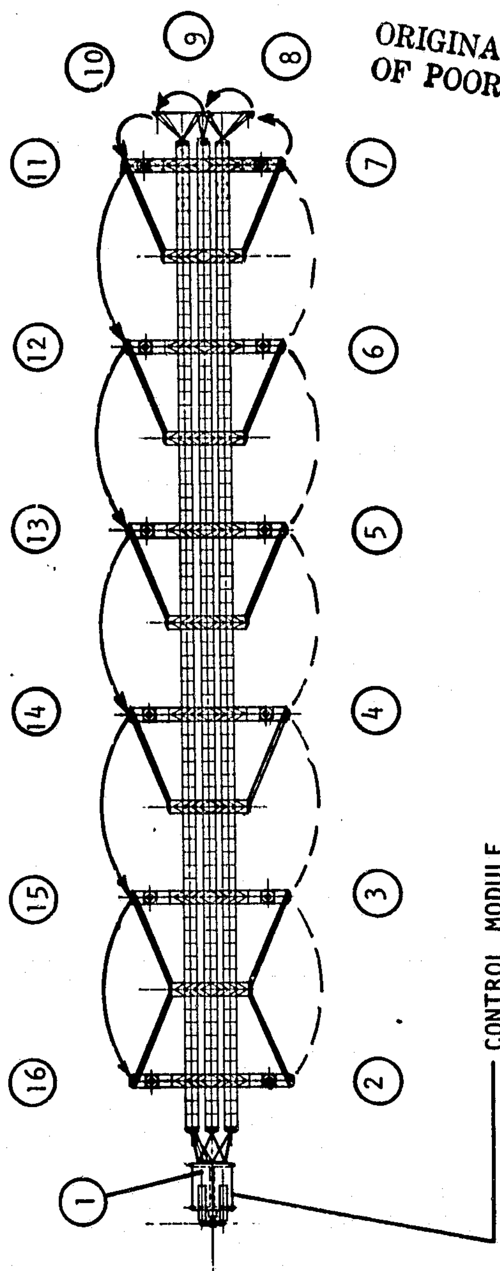

INSTALLATION SEQUENCE OF IMU's

POSITIONS 8 THROUGH 16 COVERED IN THIS ACTIVITY

FORM 994-B-1 REV 12-78

ACTIVITY 38.1

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

37.0 Perform Alignment of Attach Ports on Starboard Side → 38.1 Rotate Constr. Fix. & Return Alignment IMU to Orbiter

→ 38.2 Prepare Orbiter and Platform for Separation

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP Verification Platform
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

The activity consists of returning IMU No. 1 assembly (which is on the RMS) to the baseline mounting fixture and latching it in place, then rotating the construction fixture (and platform assembly) 180 degrees to permit the RMS to retrieve IMU No. 2 from the teleoperator docking port of the control module, and stow it in the baseline mounting fixture, where it is latched in position. The cover (if used) of the baseline mounting fixture is then closed. See Attachment 1 for delineation of steps in the operation.

TIMELINE

One hour, 49 minutes, 30 seconds (see Attachment 1)

POWER/ENERGY

Peak power, 2.2 kW; average power, 1.0 kW; energy, 6900 kJ (see Attachment 1)

CREW LOAD

One man continuously (IVA), operating RMS

TECHNOLOGY DEVELOPMENT REQUIREMENTS

None

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TIME, POWER, AND ENERGY ESTIMATION FOR ROTATING CONSTR. FIXTURE & RETURNING ALIGNMENT IMU's TO ORB. BAY

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
THE RMS HAS JUST REMOVED THE IMU NO. 1 ASSEMBLY FROM THE ATTACH PORT OF THE LAST CROSSBEAM AND THE ALIGNMENT MEASUREMENT IS COMPLETE.				
1. TRANSPORT IMU NO. 1 ASSY TO THE BASELINE MOUNTING FIXTURE IN THE ORBITER BAY AND INSTALL IT.	900	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	760.5 472.5
2. BY REMOTE CONTROL FROM THE CREW CABIN, CLOSE THE LATCHES WHICH SECURE THE IMU NO. 1 ASSEMBLY IN THE BASELINE MOUNTING FIXTURE.	30	0.02 (f) 1.050 (b)	0.02 (f) 0.525 (b)	12 16
3. BY REMOTE CONTROL FROM CREW CABIN, ROTATE THE CONSTRUCTION FIXTURE 180° ABOUT THE BERTHING PORT AXIS TO PERMIT RMS REACH TO THE CONTROL MODULE.	3600	0.10 (g) 1.050 (b)	0.10 (g) 0.525 (b)	360 1890
4. RELEASE THE RMS AND MOVE IT TO THE VICINITY OF IMU NO. 2 WHICH IS INSTALLED ON THE TELEOPERATOR DOCKING PORT ON THE CONTROL MODULE (CM).	600	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	507 315
5. USE THE RMS TO GRASP IMU NO. 2 ASSEMBLY	300	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	253.5 157.5
6. BY REMOTE CONTROL FROM THE CREW CABIN & VIA THE TTC ANTENNA, RELEASE THE LATCHES WHICH SECURE THE IMU NO. 2 ASSEMBLY TO THE TELEOPERATOR DOCKING PORT ON THE CM.	30	0.02 (f) 1.050 (b)	0.02 (f) 0.525 (b)	0.6 16
7. USE THE RMS TO TRANSPORT THE IMU NO. 2 ASSEMBLY TO THE BASELINE MOUNTING FIXTURE IN THE ORBITER BAY AND INSTALL IT.	900	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	760.5 472.5
8. BY REMOTE CONTROL FROM THE CREW CABIN, CLOSE THE LATCHES WHICH SECURE IMU NO. 2 ASSEMBLY IN THE BASELINE MOUNTING FIXTURE.	30	0.02 (f) 1.050 (b)	0.02 (f) 0.525 (b)	0.6 16
9. RELEASE THE RMS AND MOVE IT AWAY FROM THE BASELINE MOUNTING FIXTURE	120	0.845 (a) 1.050 (b)	0.845 (a) 0.525 (b)	101.4 63

ACTIVITY 38.1

ATTACHMENT 1

SHEET 2 OF 2

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
9. BY REMOTE CONTROL FROM THE CREW CABIN, CLOSE THE COVER ON THE BASELINE MOUNTING FIXTURE.	60	0.02 (f) 1.050 (b)	0.02 (f) 0.525 (b)	0.6 '31
SUBTOTAL	6570	1.915	1.332	6206.2
RMS LIGHTING TV & HEATER	2970 2970	0.173 0.070	0.137 0.057	513.8 169.3
SUMMARY	6570 (109 MIN., 30 SEC)	2.158 (d)	1.049 (e)	6889.3

NOTES

(a) BASIC RMS
(b) RMS HEATER
(-) --
(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.
(e) AVERAGE POWER = $\frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$
(f) LATCH
(g) CONSTRUCTION FIXTURE ROTATOR

ACTIVITY 38.2

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

37.0 Perform Alignment of Attach Ports on Starboard Side → 38.1 Return Alignment IMU to Orbiter

37.0 Perform Alignment of Attach Ports on Starboard Side → 38.2 Configure Platform for Untended Operations

REFERENCE DATA

1. Drawing 42662-50, Construction Fixture
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

This activity primarily includes those operations necessary for the deployment and pre-separation checkout of the libration damping system. It will take place at completion of platform assembly, in parallel with the stowage of return cargo in the payload bay, and will be followed by the orbiter separation operations (see Attachments 1 and 3).

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture
2. Lighting and TV system

TIMELINE

Estimated 20 minutes for boom deployment, and 28.0 minutes for pre-separation electronic checkout (see Attachment 2).

POWER/ENERGY

Peak power, 2.1 kW; average power, 0.8 kW; energy, 1500 kJ (see Attachment 2)

CREW LOAD

EVA: 2.0 men continuously
EVA: None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Tri-beam construction fixture libration damping system

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CHECKED BY:		ACTIVITY 38.2
DATE:	CONFIGURE PLATFORM FOR UNTENDED OPERATIONS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1

LIBRATION DAMPING SYSTEM CONFIGURATION

The libration damping system will consist of: two cold gas RCS modules with 1/2-lb thrusters, each mounted on a foldable boom attached to the construction fixture; a battery module; a computer module; a TT&C module; a cryo sensor module; and two omni antennas. The entire system will be packaged and transported as a part of the main construction fixture. Sheet 3 of Drawing 42662-50, as revised, shows the general arrangement and indicates how the booms will unfold into operating position (as shown on Attachment 3). Power for boom deployment will be furnished by the orbiter.

RETURN CARGO STOWAGE

The cherry picker, alignment measurement equipment, and checkout equipment have all been stowed previously following usage. The cross-brace strut canister cannot be rotated to its stowed position until separation of the orbiter from the construction fixture.

ACTIVITY 38.2

ATTACHMENT 2

TIME, POWER, AND ENERGY ESTIMATION FOR CONFIGURING PLATFORM FOR UNTENDED OPERATIONS (38.2)

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. POSITION RMS FOR VIEWING OF LIBRATION DAMPING RCS APPENDAGE DEPLOYMENT.	120	0.845 (a) 1.050 (b) 0.243 (c)	0.845 (a) 0.525 (b) 0.230 (c)	101.4 63.0 27.6
2. DEPLOY RCS APPENDAGE BY USE OF MOTOR DRIVES IN CONSTRUCTION FIXTURE.	240	0.1 (f) 0.466 (g) 1.050 (b) 0.243 (c)	0.1 (f) 0.466 (g) 0.525 (b) 0.230 (c)	24.0 107.0 126.0 55.2
3. MOVE RMS TO GRAPPLE CONSTRUCTION FIXTURE IN PREPARATION FOR SEPARATION (CONCURRENTLY WITH FOLLOWING TASK).	(120)	0.845 (d) 0.243 (c)	0.845 (a) 0.230 (c)	101.4 27.6
4. PERFORM ELECTRONIC CHECKOUT OF THE TT&C, POWER DISTRIBUTION, AND RCS CONTROL SYSTEM IN PREPARATION FOR UNATTENDED OPERATIONS.	1320	(NEGLIGIBLE) 1.050 (b)	 0.525 (b)	10.0 693.0
5. TRANSLATE ETVP APPROX. 8 METERS TO CLEAR LIBRATION DAMPER RCS PLUMES FROM CROSSBEAMS	240	0.1 (h) 1.050 (b) 0.233 (i)	0.1 (h) 0.525 (b) 0.223 (i)	24.0 126.0 26.8
SUMMARY	1800	2.138 (d)	0.841 (e)	1513.0

NOTES

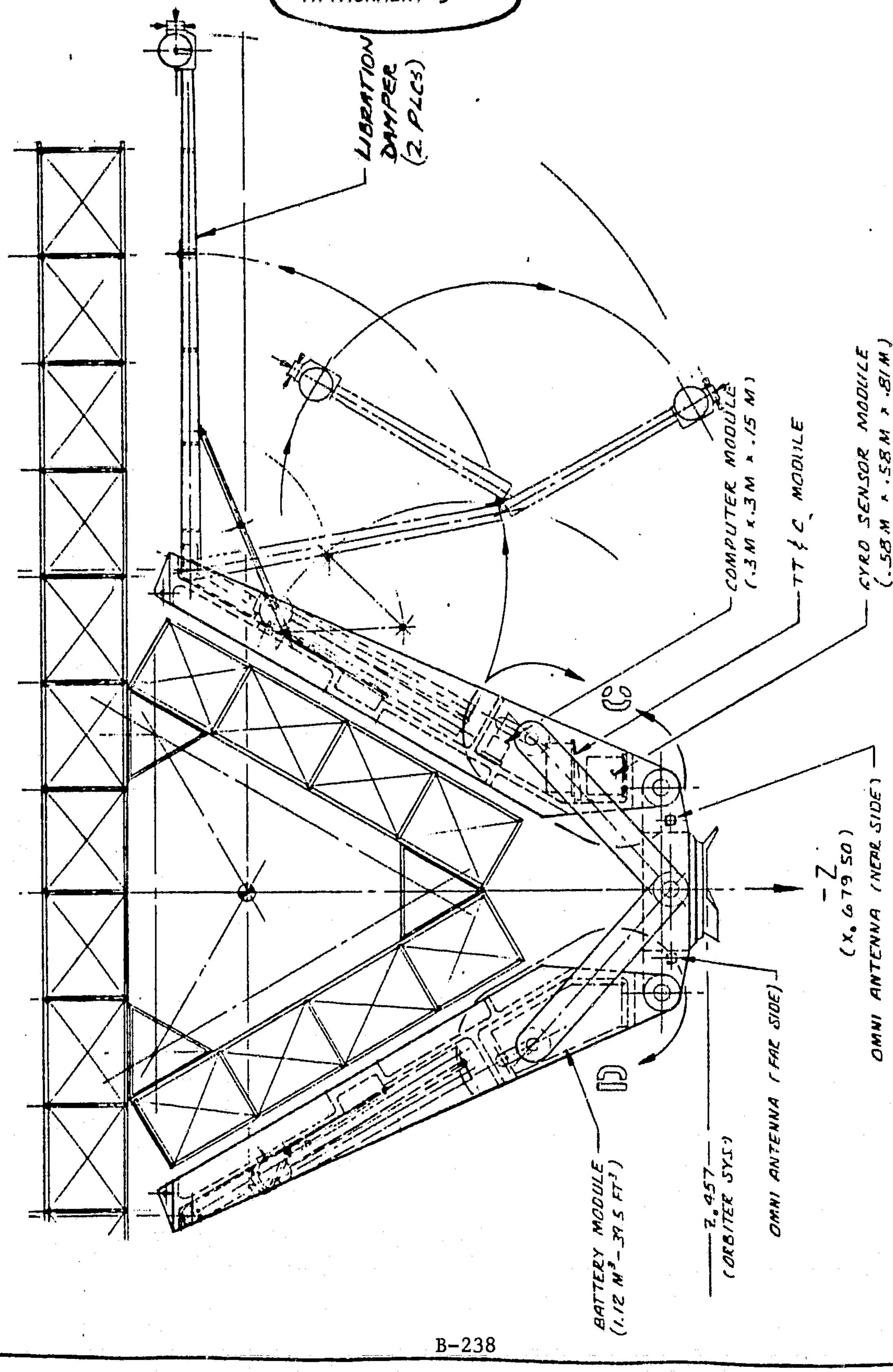
(a) BASIC RMS; (b) RMS HEATER; (c) RMS WRIST LIGHT, WRIST AND ELBOW TV CAMERAS, AND HEATERS; (d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \frac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) LIBRATION DAMPER EXTENSION DRIVES; (g) ONE 200-W LAMP AND TV CAMERA ON EACH SIDE OF CONSTRUCTION FIXTURE YOKE; (h) CONSTRUCTION FIXTURE ROLLER DRIVES; (i) CONSTR. FIXTURE LAMP & TV AT BASE OF YOKE.

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 38.2
DATE:	CONFIGURE CONSTRUCTION FIXTURE FOR UNTENDED OPNS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



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ACTIVITY 41.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

Dock Orbiter to Fixture—Prepare for Construction → 41.0 Prepare Construction System for Construction Operations → 42.0 Install RCS Pods

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Manned Remote Work Station Development Article Final Report—Executive Summary, Grumman Aerospace Corporation, Report NSS-MR-RP008, March 1979

DESCRIPTION OF ACTIVITY

Included in this activity are all those operations necessary to prepare the construction system for construction operations. Attachment 1 delineates the steps in the operations.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system
3. RMS with astronaut cherry picker

TIMELINE

60 minutes (see Attachment 1)

POWER/ENERGY

Peak power, 2.771 kW; average power, 1.890 kW; energy, 6803 kJ
(see Attachment 1)

CREW LOAD

IVA astronaut—60 minutes, continuous
EVA astronaut—None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

1. Tri-beam construction fixture system
2. RMS with astronaut cherry picker and end effectors

ATTACHMENT 1

TIME, POWER AND ENERGY ESTIMATION FOR PREPARING CONSTRUCTION SYSTEM FOR CONSTRUCTION OPERATIONS (ACTIVITY 41.0)

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. BRING RMS FROM ITS FINAL POSITION AT THE END OF DOCKING OPERATIONS INTO A POSITION AFFORDING AN ADVANTAGEOUS VIEW OF THE PRELIMINARY ELECTRICAL CHECKOUT TO FOLLOW.	300	0.845 (a) 1.050 (b) 0.033 (k) 0.173 (j) 0.200 (f) 0.400 (g) 2.701	0.845 (a) 0.525 (b) 0.023 (k) 0.173 (j) 0.200 (f) 0.400 (g) 2.166	650
2. A PRELIMINARY ELECTRICAL CHECK OF THE CONSTRUCTION FIXTURE ELECTRICAL SYSTEM MUST BE PERFORMED TO CONFIRM THAT A SATISFACTORY ELECTRICAL CONNECTION WAS MADE AT DOCKING. THIS CHECK WILL INCLUDE CONSTRUCTION FIXTURE TV AND LIGHTING, BUT WILL NOT INCLUDE PLATFORM TRANSLATION DRIVE SYSTEM OR THE CONSTRUCTION FIXTURE ROTATION DRIVE.	600	1.050 (b) 0.033 (k) 0.033 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.889	0.525 (b) 0.023 (k) 0.023 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.344	806
3. TO REDUCE THE DANGER OF COLLISON BETWEEN THE RMS AND THE RCS BOOMS OF THE LIBRATION DAMPING SYSTEM, WHICH EXTEND OUT FROM THE CONSTRUCTION FIXTURE, THESE BOOMS MUST BE RETRACTED INTO THE STOWED POSITION.	300	1.050 (b) 0.033 (k) 0.033 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.889	0.525 (h) 0.023 (k) 0.023 (h) 0.173 (j) 0.200 (f) 0.400 (g) 1.344	403
4. MANEUVER THE RMS INTO POSITION AND ATTACH THE CHERRY PICKER WHICH IS STOWED APPROXIMATELY IN THE CENTER OF THE ORBITER CARGO BAY; PROPER ATTACHMENT IS CONFIRMED BY A CHECKOUT OF CHERRY PICKER FUNCTIONS. AT COMPLETION OF CHECKOUT, THE CHERRY PICKER MUST BE PARKED AS NEAR AS PRACTICAL TO THE AIRLOCK DOOR AND ADJACENT TO HANDHOLDS WHICH WILL PERMIT THE EVA ASTRONAUT TO EGRESS AND CLIMB INTO POSITION ABOARD IT.	1800	0.845 (a) 1.050 (b) 0.070 (k) 0.033 (h) 0.173 (j) 0.200 (f) 0.400 (g) 2.771	0.845 (a) 0.525 (b) 0.057 (k) 0.023 (h) 0.173 (j) 0.200 (f) 0.400 (g) 2.223	4001

ACTIVITY 41.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
5. WHEN THE CHERRY PICKER IS READY TO RECEIVE HIM, THE EVA ASTRONAUT EGRESSES FROM THE AIRLOCK AND PROCEEDS VIA THE HANDHOLDS TO IT AND POSITIONS HIMSELF ABOARD. AN ON-BOARD FUNCTIONAL CHECK IS PERFORMED AND THEN THE CHERRY PICKER IS MANEUVERED INTO POSITION FOR NEXT ACTIVITY.	600	1.050 (b) 0.033 (h) 0.070 (c) 0.173 (j) 0.200 (f) 0.400 (g) 0.180 (i) 2.106	0.525 (b) 0.023 (h) 0.070 (c) 0.173 (j) 0.200 (f) 0.400 (g) 0.180 (i) 1.571	943
SUMMARY	3600 (60 MINUTES)	2.771 (d)	1.890 (e)	6803 1.890 kWh

NOTES

(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER
(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

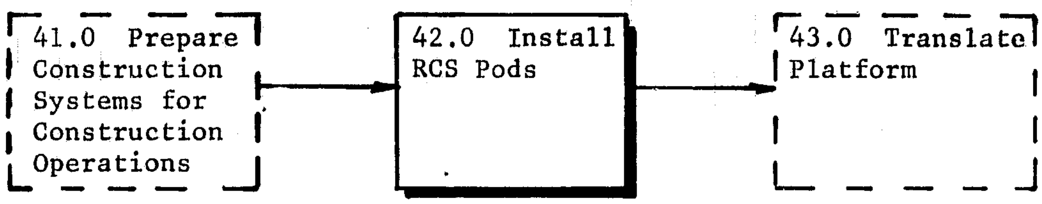
(f) ORBITER LIGHTS
(g) CONSTRUCTION FIXTURE LIGHTS
(h) CONSTRUCTION FIXTURE TV & CAMERA
(j) RMS LIGHTS
(k) RMS TV & HEATER
(i) CHERRY PICKER LIGHTS

ACTIVITY 42.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM

ACTIVITY



REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP

2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

This activity includes those operations necessary to install the two RCS pods on opposite ends of a crossbeam at one end or the other of the platform. Since there is one RCS pod bearing crossbeam at each end of the platform, this activity must be accomplished twice during the mission to install a total of four RCS pods. Attachment 1 delineates the steps in the activity, timelines, power and energy requirements. Attachment 2 provides a detail discussion of the operations.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-Beam Construction Fixture System

2. Lighting and TV System

3. RMS with Astronaut Cherry Picker

TIMELINE: 87 minutes (see Attachment 1)

POWER/ENERGY:

Peak power, 2.992 kW; average power, 2.313 kW; total energy, 12,075 kJ (see Attachment 1)

CREW LOAD

IVA—Astronaut, 87 minutes support
EVA—Astronaut, 87 minutes continuous

TECHNOLOGY DEVELOPMENT REQUIREMENTS: (1) tri-beam construction fixture system; (2) RMS with astronaut cherry picker.

ATTACHMENT 1

TIME, POWER, AND ENERGY SUMMATION FOR ACTIVITY 42.0—INSTALL RCS PODS

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. POSITION PLATFORM	120	0.845 (a) 1.050 (b) 0.250 (c) 0.400 (f) 0.047 (h)	0.845 (a) 0.525 (b) 0.250 (c) 0.400 (f) 0.034 (h)	101.4 63.0 30.0 48.0 4.1 294.5
2. GRASP RCS MODULE NO. 1	300	SAME	SAME	736.3
3. TRANSPORT MODULE TO PLATFORM	1320	SAME	SAME	3239.5
4. ATTACH MODULE TO CROSSBEAM	480	SAME	SAME	1178.0
5. RETURN CHERRY PICKER	300	SAME	SAME	736.3
6. GRASP RCS MODULE NO. 2	300	SAME	SAME	736.3
7. TRANSPORT MODULE TO PLATFORM	1620	SAME	SAME	3975.8
8. ATTACH MODULE TO CROSSBEAM	480	SAME	SAME	1178.0
9. RETURN CHERRY PICKER	300	SAME	SAME	736.3
SUMMARY	5220	2.992 (d)	2.313 (e)	12,074.7

(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER
(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY.

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) ORBITER LIGHTS
(g) CONSTRUCTION FIXTURE LIGHTS
(h) CONSTRUCTION FIXTURE TV AND CAMERA

ATTACHMENT 2

The process of installing the RCS module begins with the cherry picker attached to the end of the RMS and manned by an astronaut. The four RCS modules are contained in a revolving cradle which positions each module ready for pick-up. After the RMS/cherry picker has locked on to a module, the support trunnions are withdrawn via remote control from the orbiter cabin. The platform is translated through the construction fixture until the first long crossbeam is positioned 8.5 m outboard from the centerline of the orbiter and construction fixture as shown in Attachment 3.

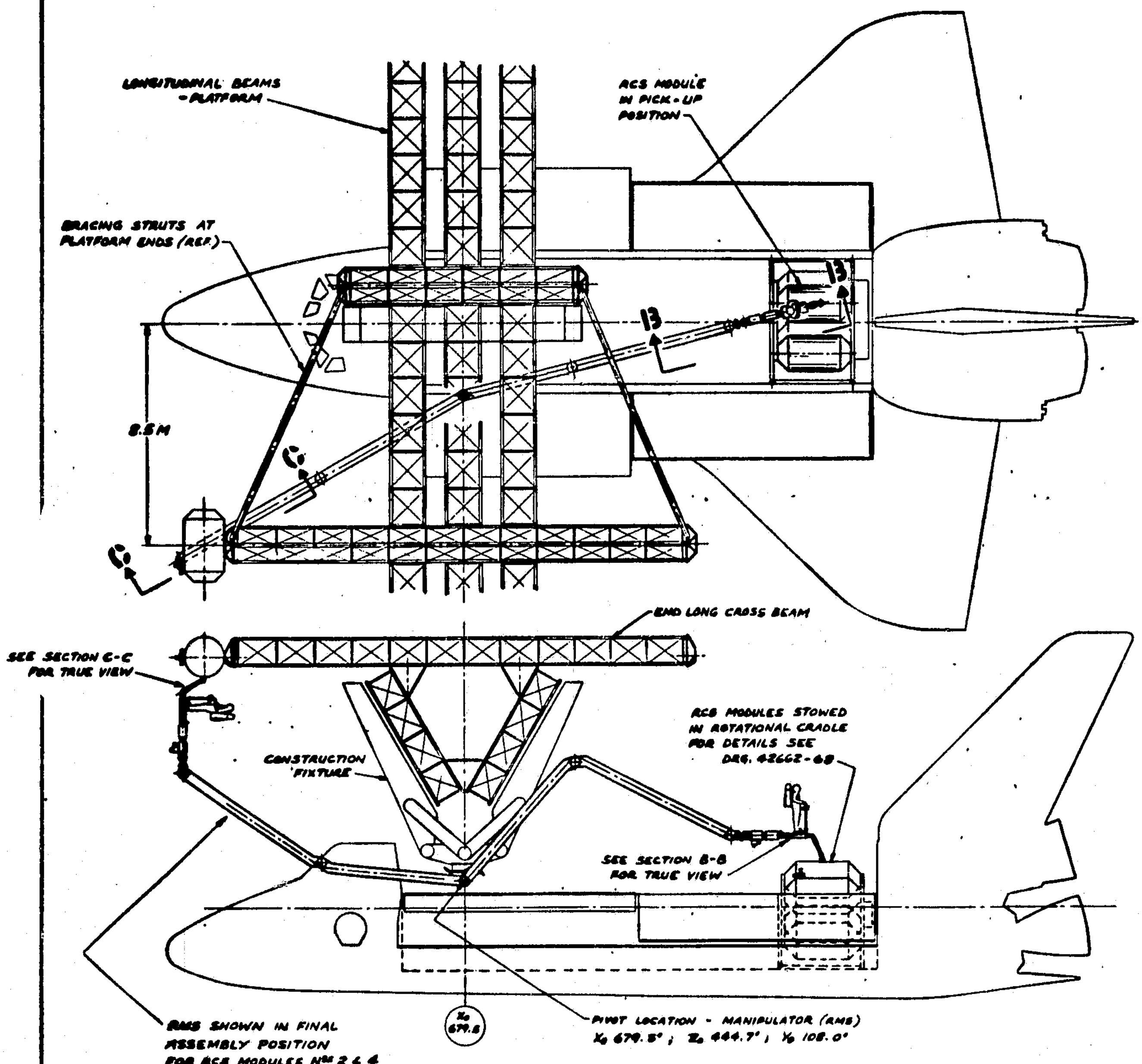
Translating and aligning the RCS module for attachment involves several distinct operations. The lower arm of the RMS is raised approximately 30 degrees so that the upper and lower arm sections are in line. The joint in the upper arm of the modified RMS is rotated 180° in one direction. Concurrently, the wrist joint is rotated 180° in the opposite direction. This dual action has resulted in an orientation of the RMS which permits movement of the RCS module to the end of the crossbeam attach port. Attachment 4 illustrates these operations. The RCS module female attach port is berthed and locked to the male attach port on the end of the crossbeam. Mechanized connectors are then remotely actuated to complete the electrical connections across the berthed interface. Installation of the second RCS module is basically the same as just described, except that the RMS is translated to the opposite end of the first crossbeam, No. 1.

Subsequently, the tri-beam platform is translated its full length through the construction fixture, rotated 180° around the end of the platform to the position shown in Attachment 5. From this position, RCS modules No. 3 and 4 are installed.

With all four RCS modules installed, the orbiter is rotated back 180° and the platform translated its full length, which places the orbiter back at the forward end of the platform adjacent to the control module, ready for the system checkout activity.

PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 42.0
DATE:	INSTALL RCS PODS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



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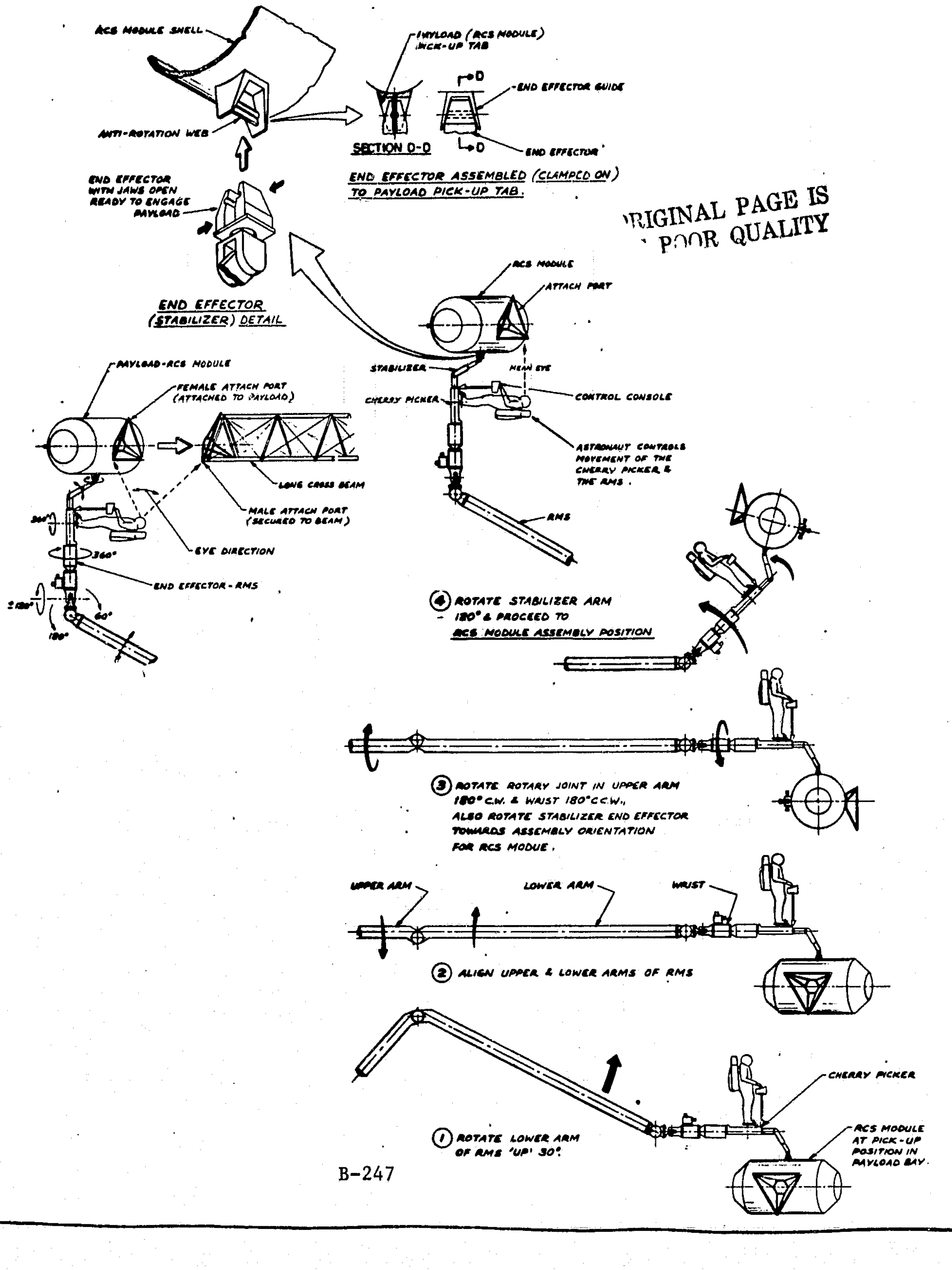
PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 42.0
DATE:	INSTALL RCS PODS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 4



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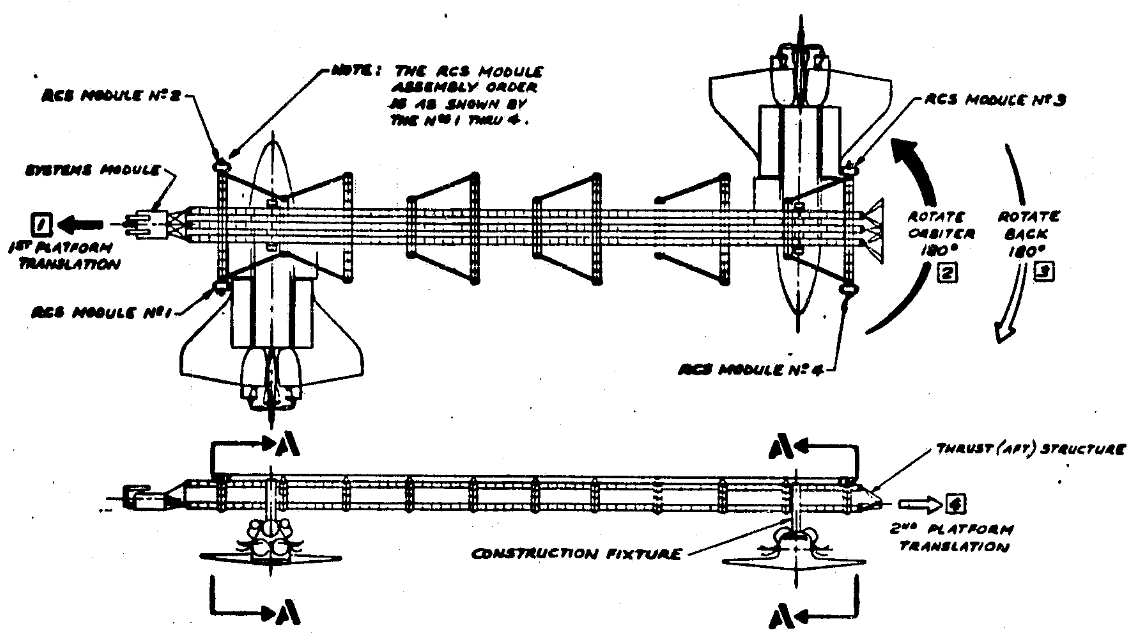
PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 42.0
DATE:	INSTALL RCS PODS	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 5



RELATIONSHIP OF ORBITER TO PLATFORM FOR RCS MODULE ATTACHMENT

NOTE: ITEMS 1 & 2 REQUIRED FOR ASSEMBLY OF RCS MODULES No 3 & No 4.
ITEMS 3 & 4 RETURNS ORBITER BACK TO THE SYSTEMS MODULE END FOR THE NEXT (CHECK-OUT) PROCEDURE.

ACTIVITY 43.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

42.0 Install RCS Pods No. 1 & 2	→	43.0 Translate Platform to Opposite End	→	44.0 Rotate 180°

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base
3. Drawing 42662-50, Tri-Beam Construction Fixture

DESCRIPTION OF ACTIVITY

The platform is translated through the construction fixture rollers to the opposite end in order to bring the next RCS pod mounting point within reach of the RMS/cherry picker.

CONSTRUCTION SUPPORT EQUIPMENT

Tri-beam construction fixture

TIMELINE

63 minutes, 136 meters @ 2.16 meters/minute

POWER/ENERGY

Peak power, 2.067 kW; average power, 1.180 kW; energy, 6160 kJ

CREW LOAD

IVA—Approximately 0.5, continuously monitoring
EVA—None

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Construction fixture roller drive and control system

ACTIVITY 44.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING AND TECHNOLOGY VERIFICATION PLATFORM (ETVP)

ACTIVITY

43.0 Translate Platform to Opposite End	→	44.0 Rotate Platform 180°	→	42.0 (Repeat) Install RCS Pods No. 3 & 4

REFERENCE DATA

1. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
2. Space Construction Data Base

DESCRIPTION OF ACTIVITY

At this point, it will be necessary to rotate the platform 180 degrees to bring the desired work areas within range of the RMS. A rotation mechanism has been included in the construction fixture mounting arrangement to accommodate this requirement.

CONSTRUCTION SUPPORT EQUIPMENT

1. Tri-beam construction fixture system
2. Lighting and TV system

TIMELINE

Rotation time = 60 minutes, based on an angular velocity of
3 degrees/minute

POWER/ENERGY

Peak power, 2.067 kW; average power, 1.629 kW; energy 5865 kJ

CREW LOAD

IVA astronaut— 60 minutes, continuous
EVA astronaut— 60 minutes, monitoring

TECHNOLOGY DEVELOPMENT REQUIREMENTS

Tri-beam construction fixture system

ACTIVITY 45.0

CONSTRUCTION ACTIVITY DATA SHEET

PROJECT ENGINEERING TECHNOLOGY AND VERIFICATION PLATFORM (ETVP)

ACTIVITY

43.0 (Repeat) Translate Platform to Forward End → 45.0 Activate and Check Out Platform Syst.

REFERENCE DATA

1. Engineering and Technology Verification Platform (ETVP) Definition
2. Drawing 42662-45, Rockwell Tri-Beam Concept, ETVP
3. Drawing 42662-67, Shuttle Bay Packaging, Ground Flight Platform
4. Drawing 42662-74, Solar Array Assembly

DESCRIPTION OF ACTIVITY

The data/power umbilical will be withdrawn from the payload bay and connected to the platform's control module, using the EVA crewman in the RMS/cherry picker (see Attachment 1). The control module will be powered up and put through a self-test series of checks (see Attachment 4). For safe deployment of the solar array, the platform will be translated outboard to clear the wing surface. The solar array will be fully deployed and checked through the rotary joint. The array will then be retracted and the platform translated inboard so that the umbilical may be disconnected. Final activation, prior to orbiter separation, will be accomplished by translating the platform, deploying the solar array, and retesting the system—with verification over the RF link to the cabin.

CONSTRUCTION SUPPORT EQUIPMENT

RMS, cherry picker, power/data buffer unit (with umbilical)

TIMELINE: 7 hours (see Attachment 4)

POWER/ENERGY

Peak power, 5.277 kW; average power, 2.371 kW; energy, 54,495 kJ (see Attachment 4)

CREW LOAD

IVA—one crew, monitoring
EVA—one crew, continuously

TECHNOLOGY DEVELOPMENT REQUIREMENTS: Development of software that is associated with checkout equipment and operations.

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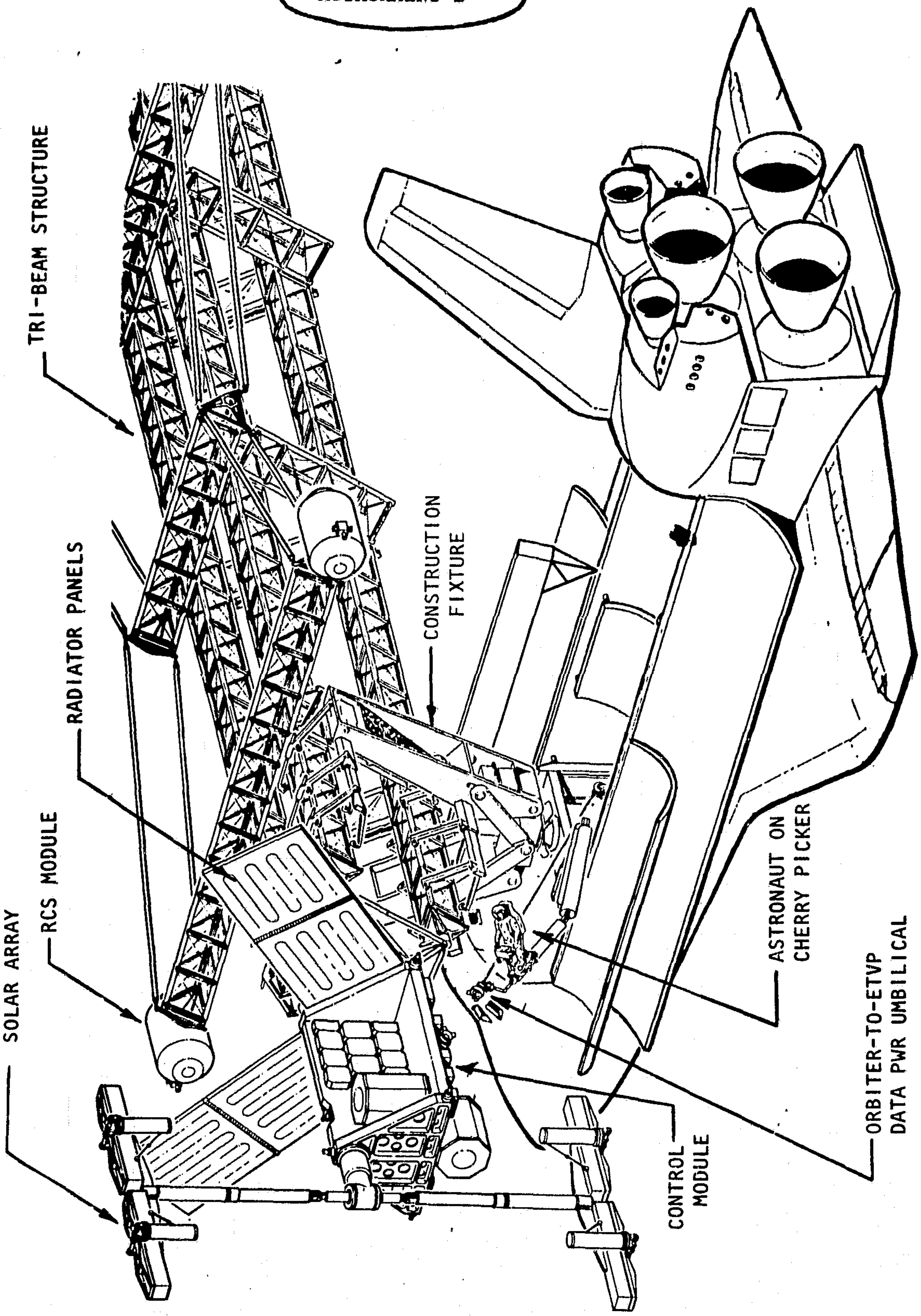
PREPARED BY:	Satellite Systems Division Space Systems Group — Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 45.0
DATE:	ACTIVATE AND CHECK OUT PLATFORM SYSTEM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 1



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PREPARED BY:	Satellite Systems Division Space Systems Group Rockwell International	PAGE NO. 1 OF 1
CHECKED BY:		ACTIVITY 45.0
DATE:	ACTIVATE AND CHECKOUT PLATFORM SYSTEM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 2

CHECKOUT CONCEPT

The checkout concept for the platform is schematically represented in Attachment 3.

The platform's systems are controlled and monitored within the TT&C subsystem by the command and data (C&D) processor. The subsystem includes a platform self-test element (primarily in the form of software) which, upon command, automatically steps the platform's subsystem through sets of test operations and verifies the performance to the line/spare-replaceable-unit (LRU) level. Performance deviations outside spec limits are reported over the RF or umbilical link to the orbiter or to ground/mission control.

A test module element is included to verify the integrity of the self-test. This element emulates a performance model of the platform's systems—including performance deviations at the LRU level. The self-test procedure begins with a report of the measured performance of the test model.

Attachment 3 also shows the interface between the platform's checkout elements and the orbiter. The orbiter provides a power/data buffer unit (including the umbilical) which serves two functions: (1) provides external (orbiter) power at platform voltage (220 V) for systems operations and checkout; and (2) provides signal conditioning for compatibility between platform hardware and data bus streams and orbiter controls and displays in the aft cabin. In addition to the umbilical link, an RF link to the orbiter is provided for summary reports of the platform's status when the umbilical is not used.

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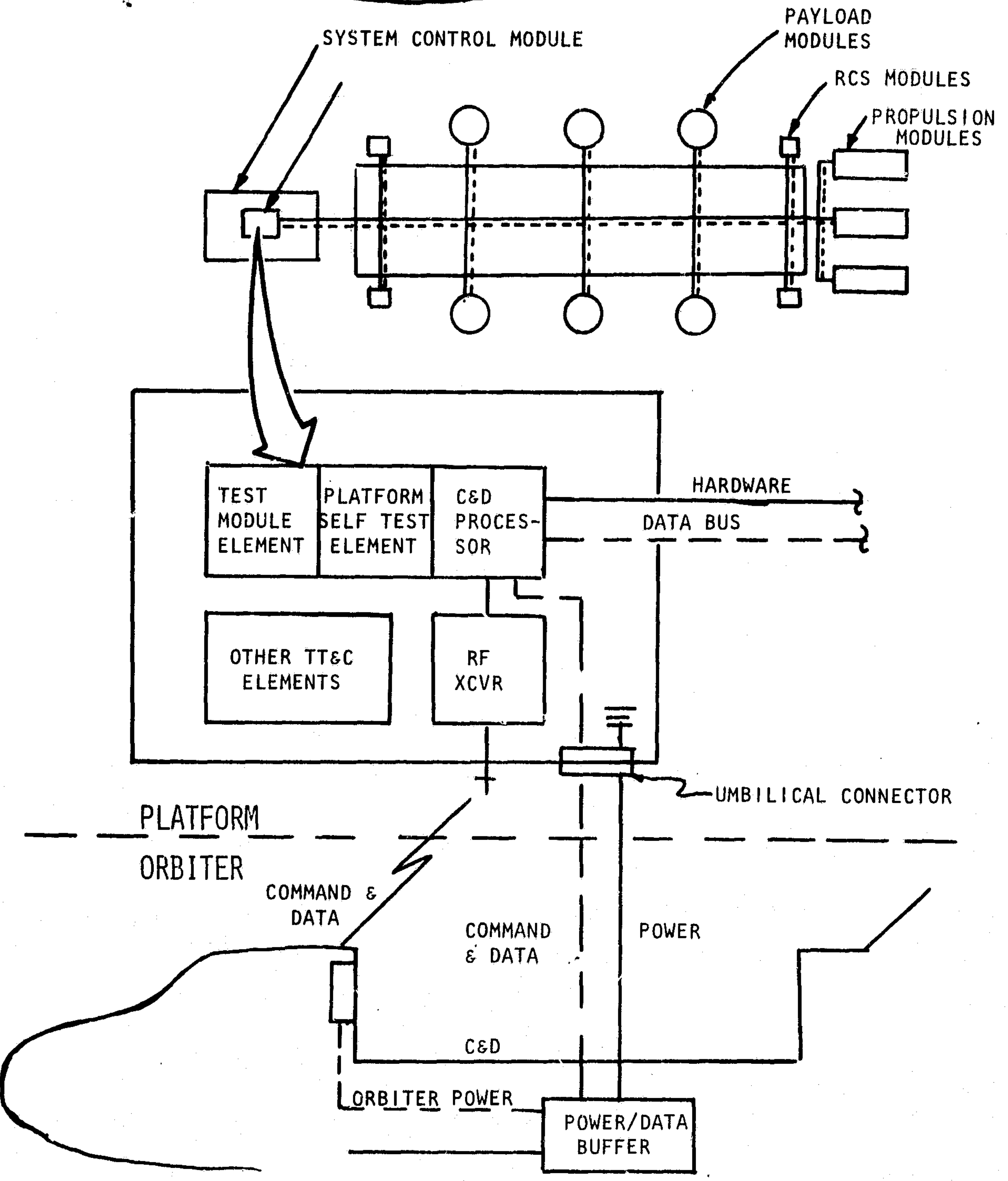
DATE:	ACTIVATE AND CHECK OUT PLATFORM SYSTEM	MODEL NO. ETVP
		DWG. NO.

ATTACHMENT 3



FORM 394-B-1 REV 12-78

ACTIVITY 45.0

ATTACHMENT 4

TIME, POWER, AND ENERGY SUMMATION FOR ACTIVATING AND CHECKING OUT PLATFORM SYSTEM (SHEET 1 OF 3)

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
1. MANEUVER THE EVA CREWMAN/CHERRY PICKER/RMS INTO POSITION TO GRASP THE UMBILICAL CONNECTOR	600	0.845 (a) 1.05 (b) 0.25 (c)	0.845 (a) 0.525 (b) 0.25 (c)	507 315 150
2. GRASP THE CONNECTOR WITH THE MANIPULATOR/STABILIZER ARM OF THE CHERRY PICKER	120	0.845 (a) 1.05 (b) 0.25 (c)	0.845 (a) 0.525 (b) 0.25 (c)	101 63 30
3. MANEUVER THE CHERRY PICKER INTO POSITION TO CONNECT THE UMBILICAL WITH THE CHECKOUT PORT OF THE CONTROL MODULE. THE UMBILICAL WILL PAY OUT (UNDER TENSION) FROM A REEL WITHIN THE POWER/DATA BUFFER UNIT LOCATED IN THE PAYLOAD BAY	600	0.845 (a) 1.05 (b) 0.25 (c)	0.845 (a) 0.525 (b) 0.25 (c)	508 315 150
4. INSERT THE CONNECTOR INTO THE CONTROL MODULE PORT AND ACTIVATE THE LATCHES WHICH WILL SECURE ALL MECHANICAL AND ELECTRICAL INTERFACES; VERIFY THE CONNECTIONS. *NOTE: At this point, control of the operations is transferred to the aft cabin control station. The EVA astronaut remains aboard the cherry picker to observe, record, communicate, and take such local action as may be required.*	300	0.845 (a) 1.05 (b) 0.25 (c)	0.845 (a) 0.525 (b) 0.25 (c)	250 160 80
5. APPLY EXTERNAL (ORBITER) POWER TO THE CONTROL MODULE MAIN BUS TO BRING ALL PLATFORM SYSTEMS UP TO OPERATING CONDITIONS (E.G., TEMPERATURE, SPEED, ETC.). HARDWIRED (RED-LINES, SAFETY) FUNCTIONS ARE MONITORED FROM THE AFT CABIN.	7200	3 (f) 1.050 (b) 0.25 (c)	3 (f) 0.525 (b) 0.25 (c)	21,600 3,780 1,800
6. ACTIVATE THE PLATFORM'S SELF-TEST SYSTEM TO STEP THROUGH THE CHECKOUT SEQUENCE; SUMMARY VERIFICATION DATA ARE TRANSMITTED OVER THE UMBILICAL TO THE AFT CABIN.	3600	3 (f) 1.050 (b) 0.25 (c)	3 (f) 0.525 (b) 0.25 (c)	10,800 1,890 900

ACTIVITY 45.0

ATTACHMENT 4

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
7. WITH ALL SYSTEMS CHECKOUT COMPLETE (ON EXTERNAL POWER), MANEUVER THE CREWMAN/CHERRY PICKER TO A POSITION WHERE THE PLATFORM CAN BE FREELY TRANSLATED THROUGH THE FIXTURE.	300	0.845 (a) 1.05 (b) 0.25 (c)	0.845 0.525 0.25	254 158 75
8. TRANSLATE THE PLATFORM TO PLACE THE EXTENDED SOLAR ARRAY BEYOND THE PORT WING TIP—TO PRECLUDE THE POSSIBILITY OF COLLISION IN THE EVENT OF FAILURE IN THE ARRAY DRIVE SYSTEM. THE UMBILICAL, WHICH REMAINS ATTACHED, IS EXTENDED FROM THE PAYLOAD BAY.	240	1.05 (b) 0.25 (c)	0.525 (b) 0.25 (c)	126 60
9. EXTEND THE SOLAR ARRAY TO ITS FULLY DEPLOYED POSITION.	900	1.0 (f) 1.050 (b) 0.25 (c)	1.0 (f) 0.525 (b) 0.25 (c)	900 473 225
10. CHECK THE SOLAR ARRAY/ROTARY JOINT FOR POWER OUTPUT AND DRIVE SYSTEM PERFORMANCE	900	1.0 (f) 1.050 (b) 0.25 (c)	1.0 (f) 0.525 (b) 0.25 (c)	900 473 225
11. SWITCH PLATFORM SYSTEMS TO INTERNAL POWER TO CHECK POWER SWITCHING AND CONTINUITY.	120	NEGLIGIBLE 1.050 (b) 0.25 (c)	NEGLIGIBLE 0.525 (b) 0.25 (c)	63 30
12. SWITCH POWER TO EXTERNAL AND RETRACT SOLAR ARRAY PANELS; CHECK RETRACTION PROCESS	1020	1.0 1.050 (b) 0.250 (c)	1.0 0.525 (b) 0.250 (c)	1020 536 255
13. TRANSLATE THE PLATFORM BACK TO ORIGINAL POSITION WHERE CHERRY PICKER CAN PERFORM UMBILICAL DISCONNECT.	240	0.1 1.05 (b) 0.25 (c)	0.1 0.525 (b) 0.25 (c)	24 126 60
14. MANEUVER THE CHERRY PICKER INTO POSITION, DISCONNECT THE UMBILICALS AND RESTOW THE UMBILICAL INTO THE POWER/DATA BUFFER UNIT	300	0.845 (a) 1.05 (b) 0.25 (c)	0.845 (a) 0.525 (b) 0.25 (c)	254 158 75
15. TRANSLATE THE PLATFORM (REPEAT 8)	240	0.1 1.050 (b) 0.25 (c)	0.1 0.525 (b) 0.25 (c)	24 126 60

ATTACHMENT 4

ACTIVITY 45.0

ACTIVITY	DURATION (sec)	PEAK POWER (kW)	AVG. POWER (kW)	ENERGY (kJ)
16. USING THE RF COMMAND LINK AND INTERNAL (BATTERY) POWER, REDEPLOY THE SOLAR ARRAY (REPEAT 10).	900	NEGLIGIBLE 1.050 (b) 0.250 (c)	NEGLIGIBLE 0.525 (b) 0.250 (c)	 473 225
17. REPEAT SELF-TEST PROCEDURE (ITEM 6) FOR CHECK OF INTEGRATED OPERATIONS AND RF LINK.	3600	0.1 1.050 (b) 0.25 (c)	0.1 0.525 (b) 0.25 (c)	360 158 900
18. MANEUVER THE CHERRY PICKER TO ITS STOWED POSITION IN THE BAY.	600	0.845 (a) 1.05 (b) 0.25 (c)	0.845 (a) 0.525 (b) 0.25 (c)	507 315 150
19. STOW/SECURE THE CHERRY PICKER	600	0.845 (a) 1.050 (b)	0.845 (a) 0.525	507 315
20. RE-ENTER THE EVA CREWMAN INTO THE AIRLOCK/CABIN	600	1.050 (b)	0.525	507
SUMMARY	22,980	5.277 (d)	2.371 (e)	54,495

NOTES:
(a) BASIC RMS
(b) RMS HEATER
(c) CHERRY PICKER
(d) PEAK POWER SUMMARY BASED UPON PEAK POWER OF INDIVIDUAL ACTIVITIES, SUBJECTIVELY ESTIMATED, BEING PERFORMED SIMULTANEOUSLY

(e) $\text{AVERAGE POWER} = \dfrac{\text{ENERGY SUMMATION}}{\text{ACTIVITY TIME SUMMATION}}$

(f) ORBITER-FURNISHED CHECKOUT POWER

APPENDIX C

MASS PROPERTIES STATEMENTS

Detail lists of cargo manifest items for each of the three construction missions are included in this appendix. The tables are arranged in order of the mission occurrence.

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WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 1

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
PLATFORM ITEMS (SATELLITE)	(11,498)	1130.1	-0.3	356.3	(12,994,214)	(-3960)	(4,096,558)
BEAM MATERIAL (ON BEAM BUILDER)	2,761	1240.9	0	422.0			
CONVERTERS/REGULATORS/SWITCH GEARS	741	1102.9	0	332.0			
INTERSECT. FITTINGS (66)	198	1236.9	-20.0	360.0			
ATTACH PORTS (28) + TELEOP. PORTS (12)	6,468	1102.9	0	332.0			
CONDUCTOR	558	955.9	0	368.0			
CORD ASSY	75	935.9	0	400.0			
ELECTRICAL INSTALLATION	697	1103.0	0	332.0			
CONSTRUCTION ITEMS	(12,052)	956.5	1.3	428.5	(11,527,342)	(15,740)	(5,091,506)
CONSTRUCTION FIXTURE INSTAL.	(5,814)	787.5	3.4	424.1	(4,578,877)	(19,740)	(2,465,682)
MAIN BEAMS	1,680	742.0	0	428.0			
BASE BEAM	526	634.0	0	428.0			
JACK ARMS	273	674.0	0	428.0			
BRIDGE BEAMS (2)	350	842.0	0	428.0			
LONGITUDINAL BEAM ROLLER SUPT. (4)	450	854.0	50.0	435.0			
BRIDGE BEAM (1)	250	842.0	0	430.0			
BEAM BUILDER SWING ARM (1)	150	750.0	0	428.0			
SPOOL BRACKETS	75	930.0	0	396.0			
MISC. ARMS, LATCHES, ETC.	396	862.0	0	405.0			
AFT TRUNNION & MOUNT	200	896.0	0	414.0			
CORD REELS (6)	59	930.0	0	440.0			
CABLE REEL (3)	220	942.0	0	370.0			
RCS BOOMS	154	902.0	0	428.0			
SOLAR ARRAY DEPLOYMENT SYST.	22	902.0	0	428.0			
FIXTURE DEPLOYMENT SYST.	132	634.0	0	428.0			
RCS BOOM DEPLOYMENT	22	902.0	0	428.0			
TT&C MODULE	41	682.0	-46.0	428.0			
RCS, COLD GAS SYSTEM	395	882.0	0	428.0			
SOLAR ARRAY, 70 FT^6 (6.5 M^2)	100	902.0	0	428.0			
BATTERIES (2)	20	682.0	46.0	428.0			
WIRE HARNESS	110	742.0	0	428.0			
ATT. REF. UNIT (GYRO SENSOR PKG)	37	682.0	-46.0	428.0			
COMPUTER MODULE	2	682.0	-46.0	428.0			
EVA WORK STATION	150	731.5	0	428.0			
BEAM BUILDER	(5,738)	1111.2	0	427.7	6,376,215	0	2,454,224
STRUCTURE	1,828	1118.9	0	424.0			
CAP FORMING	1,246	1239.0	0	424.0			
CROSS MEMBER SECT.	875	1033.0	0	432.0			
CORD SECTION	703	1033.0	0	432.0			
WELDING	57	1033.0	0	432.0			
CUTOFF	150	1033.0	0	432.0			

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 1

ITEM	WEIGHT (LB)	X_O (IN)	Y_O (IN)	Z_O (IN)	ω_x	ω_y	ω_z
BEAM BUILDER (CONT.)							
AVIONICS/CONTROLS	595	1073.0	0	432.0			
COOLING	15	1073.0	0	432.0			
THERMAL SHROUD	20	1073.0	0	432.0			
LATCH/DEPLOYMENT	249	1073.0	0	430.0			
INTERCONNECT FITTING CANISTER	(200)	1224.9	-20.0	360.0	244,980	-4000	72,000
SUPPORT FOR ATTACH PORTS	(300)	1090.9	0	332.0	327,270	0	99,600
AIRBORNE SUPPORT EQUIPMENT	(11,957)	900.7	7.1	361.8	10,769,898	84,738	4,325,713
BERTHING PLATFORM	1,200	681.9	0	364.0			
FWD CRADLE PALLET	575	681.6	0	360.0			
PALLET-CTR (STRUTS & RETURN ITEMS)	920	862.0	0	360.0			
STATION NO. 2 CRADLE	500	1072.9	0	360.0			
PALLET, AFT	1,455	1228.0	0	360.0			
AFT SUPT., BEAM MACHINE	350	1279.0	5.0	400.0			
LONG. BRIDGE FTG. STA. 659.9 (2)	172	659.9	0	404.0			
LONG. ATTACH FTG. " (2)	62	659.9	0	410.0			
LONG. BRIDGE FTG. STA. 703.2 (2)	188	703.2	0	404.0			
LONG. ATTACH FTG " (2)	62	703.2	0	410.0			
KEEL BRIDGE FTG, STA. 659.93 (1)	59	659.9	0	308.0			
KEEL ATTACH FTG, " (1)	15	659.9	0	308.0			
LONG. BRIDGE FTG, STA. 817.27 (2)	216	817.3	0	404.0			
LONG. ATTACH FTG. " (2)	62	817.3	0	410.0			
LONG. BRIDGE FTG, STA. 884.13 (2)	216	884.1	0	404.0			
LONG. ATTACH FTG, " (2)	62	884.1	0	410.0			
KEEL BRIDGE FTG. " (1)	116	884.1	0	308.0			
KEEL ATTACH FTG. " (1)	15	884.1	0	308.0			
LONG. BRIDGE FTG, STA. 895.9 (2)	216	895.9	0	404.0			
LONG. ATTACH FTG, " (2)	220	895.9	0	410.0			
LONG. BRIDGE FTG, STA. 1072.9 (2)	208	1072.9	0	404.0			
LONG. ATTACH FTG, " (2)	220	1072.9	0	410.0			
LONG. BRIDGE FTG, STA. 1175.2 (2)	322	1175.2	0	404.0			
LONG. ATTACH FTG, " (2)	62	1175.2	0	410.0			
LONG. BRIDGE FTG, STA. 1281.4 (2)	328	1281.4	0	404.0			
LONG. ATTACH FTG, " (2)	62	1281.4	0	410.0			
KEEL BRIDGE FTG, STA. 1175.2 (1)	161	1175.2	0	308.0			
KEEL ATTACH FTG, " (1)	15	1175.2	0	308.0			

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 1

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
AIRBORNE SUPPORT EQUIPMENT (CONT.)							
BRIDGE FITTING KIT (ORBITER PROVIDED	450	1148.0	25.9	395.3			
MMU FLIGHT SUPPORT STA. (2)	100	628.0	0	400.0			
MMU (2)	406	628.0	0	400.0			
MMU EXPENDABLES	80	628.0	0	415.0			
CREWMEN (2)	400	490.0	38.0	349.0			
EMU PRESS. GARMENT (2)	406	490.0	38.0	349.0			
CRYO KIT, H_2 NO. 3	370	1009.8	-76.0	302.0			
CRYO KIT, H_2	92	1009.8	-76.0	302.0			
CRYO KIT, O_2 NO. 3	366	1115.5	78.0	306.0			
CRYO, O_2	781	1115.5	78.0	306.0			
DISPLAYS AND CONTROLS	50	556.0	0	451.5			
N_2 TANK SYSTEM NO. 5	90	678.0	88.0	330.0			
N_2, NO. 5	60	678.0	88.0	330.0			
N_2 TANK SYSTEM NO. 6	90	1115.0	40.0	287.0			
N_2, NO. 6	60	1115.0	40.0	287.0			
N_2 TANK SYSTEM NO. 7	90	1115.0	-40.0	287.0			
N_2, NO. 7	60	1115.0	-40.0	287.0			
RMS ADDED END EFFECTOR	100	927.0	-83.0	445.0			
TV CAMERA	20	927.0	-83.0	445.0			
LIGHTS	20	927.0	-83.0	445.0			
TOOL BOX	50	494.0	48.0	340.0			
SEAT & RESTRAINT NO. 5	54	494.0	48.0	340.0			
SEAT & RESTRAINT NO. 6	54	494.0	28.0	340.0			
FLIGHT GARMENT (2)	28	494.0	38.0	349.0			
FLIGHT HELMET (2)	10	494.0	38.0	350.0			
ACCESSORIES, WEAR-ON (2)	16	494.0	38.0	350.0			
PERSONAL PREFERENCE KIT (2)	1	494.0	38.0	350.0			
LIFE VEST (2)	5	494.0	38.0	350.0			
TOWEL ASSY (2)	3	494.0	38.0	350.0			
PERSONAL HYGIENE KIT (2)	7	557.0	-43.0	356.0			
FOOD TRAY (2)	10	557.0	-43.0	356.0			
WATER GUN (2)	2	557.0	-43.0	356.0			
PERSONAL RESCUE SYST. (2)	100	500.0	0	355.0			
BIOMEDICAL (2)	18	500.0	0	355.0			
PERSONAL RESCUE ENCLOSURE (2)	49	500.0	0	355.0			
CARGO BAY SERVICE PANELS	100	827.0	0	370.0			
ORBITER INTERFACE WIRING	200	741.0	0	370.0			
TOTAL CARGO (UP)	35,507	993.9	2.7	380.6	35,291,454	96,518	13,513,777

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 1 (RETURN)

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
CONSTRUCTION ITEMS							
CONSTRUCTION FIXTURE ITEMS	(1,795)	861.3	0	354.2	(1,545,990)	0	(635,800)
BRIDGE BEAMS	350	850.0	0	348.0			
LONGITUDINAL BEAM ROLLER SUPT. (4)	450	850.0	0	348.0			
BRIDGE BEAM (1)	250	850.0	0	348.0			
BEAM BUILDER SWING ARM (1)	150	850.0	0	360.0			
SPOOL BRACKETS	75	850.0	0	360.0			
MISC. ARMS, LATCHES, ETC.	300	850.0	0	360.0			
CABLE REEL (3)	220	942.0	0	370.0			
BEAM BUILDER	5,738	1111.2	0	427.7	6,376,066	0	2,454,143
INTERCONNECT FITTING CANISTER	200	1224.9	-20.0	360.0	244,980	-4000	72,000
SUPPORT FOR ATTACH PORTS	300	1090.9	0	332.0	327,270	0	99,600
AIRBORNE SUPPORT EQUIPMENT	11,957	900.7	7.1	361.8	10,769,898	84,738	4,325,713
LESS	(-1,073)	1053.7	53.5	313.3	(-1,130,611)	(-47,446)	(-336,130)
MMU EXPENDABLES	-80	628.1	0	415.0			
CRYO, H_2	-92	1009.1	-76.0	302.0			
CRYO, O_2	-781	1115.5	78.0	306.0			
N_2 NO. 5 TANK	-40	678.0	88.0	330.0			
N_2 NO. 6 TANK	-40	1115.0	40.0	287.0			
N_2 NO. 7 TANK	-40	115.0	-40.0	287.0			
TOTAL, CARGO (RETURN)	18,917	958.6	1.2	383.3	18,133,593	23,292	7,251,126

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 2

ITEM	WEIGHT (LB)	X_O (IN)	Y_O (IN)	Z_O (IN)	ω_x	ω_y	ω_z
PLATFORM ITEMS	(23,660)	1123.3	-0.75	379.2	26,576,786	-17,763	8,971,483
X-BRACE STRUTS (24)	578	770.0	0	438.4			
BRIDGE STRUCT., S/A END	75	898.0	-51.0	448.0			
BRIDGE THRUST STRUCT.	324	834.0	0	384.0			
MECH, THRUST STRUCT.	44	786.0	0	384.0			
MECH, FWD MODULE TRUSS STRUCT.	22	890.0	-51.0	448.0			
ATTITUDE CONTROL	172	770.0	0	414.0			
TT&C	267	679.0	-48.0	432.0			
SYSTEM CONTROL MODULE	18,507	1129.0	0	368.0			
ROTARY JOINT ASSY	968	1275.0	0	336.0			
SOLAR ARRAY ASSY	2,703	1220.0	0	448.0			
CONSTRUCTION ITEMS	(990)	743.0	8.9	429.9	735,525	8,800	425,636
X-BRACE STRUCT. CANISTER	250	770.0	0	438.4			
CANISTER DEPLOYMENT SYSTEM	40	770.0	0	438.4			
EVA WORK STATION (CHERRY PICKER)	150	679.5	0	472.0			
INERTIAL ALIGNMENT UNITS (2)	550	746.0	16.0	414.0			
AIRBORNE SUPPORT EQUIPMENT	(8,957)	794.8	9.8	355.0	7,118,698	87,286	3,180,024
BERTHING PLATFORM	1,200	681.9	0	364.0			
FWD CRADLE PALLET	575	681.6	0	360.0			
CRADLE, CHECKOUT EQUIPMENT	150	730.7	0	365.0			
CRADLE, FWD, STRUCT. SUPT.	150	770.0	0	365.0			
CRADLE, AFT, STRUCT. SUPT.	150	959.0	0	365.0			
LONGERON BRIDGE FTG. STA. 659.9 (2)	172	659.9	0	404.0			
LONGERON ATTACH FTG. " (2)	62	659.9	0	410.0			
LONGERON BRIDGE FTG. STA. 703.2 (2)	188	703.2	0	404.0			
LONGERON ATTACH FTG. "	62	703.2	0	410.0			
KEEL BRIDGE FTG. STA. 659.93 (1)	59	659.9	0	308.0			
KEEL ATTACH FTG. STA. 659.93 (1)	15	659.9	0	308.0			
LONGERON BRIDGE FTG. STA. 730.73 (2)	188	730.7	0	404.0			
LONGERON ATTACH FTG. " (2)	62	730.7	0	410.0			
KEEL BRIDGE FTG. " (1)	96	730.7	0	308.0			
KEEL ATTACH FTG. " (1)	15	730.7	0	308.0			
LONGERON BRIDGE FTG. STA. 770.07 (2)	200	770.1	0	404.0			
LONGERON ATTACH FTG. "	62	770.1	0	410.0			
KEEL BRIDGE FTG. " (1)	119	770.1	0	308.0			
KEEL ATTACH FTG. " (1)	15	770.1	0	308.0			
LONGERON BRIDGE FTG. STA. 958.87 (2)	244	958.9	0	404.0			
LONGERON ATTACH FTG. " (2)	62	958.9	0	410.0			
KEEL BRIDGE FTG. " (1)	144	958.9	0	308.0			
KEEL ATTACH FTG. " (1)	15	958.9	0	308.0			

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 2

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
AIRBORNE SUPPORT EQUIPMENT (CONT.)							
LONGERON BRIDGE FTG. STA. 1033.6 (2)	232	1033.6	0	404.0			
LONGERON ATTACH FTG. " (2)	62	1033.6	0	410.0			
KEEL BRIDGE FTG. " (1)	167	1033.6	0	308.0			
KEEL ATTACH FTG. " (1)	15	1033.6	0	308.0			
LONGERON BRIDGE FTG. STA. 1222.4 (2)	276	1222.4	0	404.0			
LONGERON ATTACH FTG. " (2)	62	1222.4	0	410.0			
KEEL BRIDGE FTG. " (1)	255	1222.4	0	308.0			
KEEL ATTACH FTG. " (1)	15	1222.4	0	308.0			
BRIDGE FITTINGS, ORBITER PROVIDED	-450	1148.0	25.9	395.3			
MMU FLIGHT SUPPORT STA. (2)	100	628.0	0	400.0			
MMU (2)	406	628.0	0	400.0			
MMU EXPENDABLES	80	628.0	0	415.0			
CRYO KIT, H_2 NO. 3	370	1009.8	-76.0	302.0			
CRYO, H_2	92	1009.8	-76.0	302.0			
CRYO KIT, O_2 NO. 3	366	1115.5	78.0	306.0			
CRYO, O_2	781	1115.5	78.0	306.0			
DISPLAY AND CONTROLS	50	556.0	0	451.5			
N_2 TANK SYSTEM NO. 5	90	678.0	88.0	330.0			
N_2, NO. 5	60	678.0	88.0	330.0			
N_2 TANK SYSTEM NO. 6	90	1115.0	40.0	287.0			
N_2, NO. 6	60	1115.0	40.0	287.0			
CREWMEN (2)	400	490.0	38.0	349.0			
EMU PRESS. GARMENT (2)	406	490.0	38.0	349.0			
RMS ADDED END EFFECTOR	100	927.0	-83.0	445.0			
TV CAMERA	20	927.0	-83.0	445.0			
LIGHTS	20	927.0	-83.0	445.0			
TOOL BOX	50	494.0	48.0	340.0			
SEAT & RESTRAINT, NO. 5	54	494.0	48.0	340.0			
SEAT & RESTRAINT, NO. 6	54	494.0	28.0	340.0			
FLIGHT GARMENT (2)	28	494.0	38.0	349.0			
FLIGHT HELMET (2)	10	494.0	38.0	350.0			
ACCESSORIES, WEAR-ON (2)	16	494.0	38.0	350.0			
PERSONAL PREFERENCE KIT (2)	1	494.0	38.0	350.0			
LIFE VEST (2)	5	494.0	38.0	350.0			
TOWEL ASSY (2)	3	494.0	38.0	350.0			
PERSONAL HYGIENE KIT (2)	7	557.0	-43.0	356.0			
FOOD TRAY (2)	10	557.0	-43.0	356.0			
WATER GUN (2)	2	557.0	-43.0	356.0			
PERSONAL RESCUE SYST. (2)	100	500.0	0	355.0			
BIOMEDICAL (2)	18	500.0	0	355.0			
PERSONAL RESCUE ENCLOSURE (2)	49	500.0	0	355.0			

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 2

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
AIRBORNE SUPPORT EQUIPMENT (CONT.)							
CARGO BAY SERVICE PANELS	100	827.0	0	370.0			
ORBITER INTERFACE WIRING	200	741.0	0	370.0			
LITHIUM HYDROXIDE CANISTERS (4)	28	489.0	7.0	320.0			
FECAL BAGS	2	470.0	-41.0	335.0			
URINE BAGS	2	470.0	-41.0	335.0			
VOMITUS BAGS	2	470.0	-41.0	335.0			
TRASH CONTAINER	1	470.0	-41.0	335.0			
FOOD, NORMAL CONSUMPTION	27	465.0	-65.0	368.0			
FOOD, CONTINGENCY CONSUMPTION	20	465.0	-65.0	368.0			
LiOH, EVA RECHARGES (4)	22	494.0	38.0	349.0			
SPARE BATTERY, EVA	16	494.0	38.0	349.0			
TOTAL CARGO, UP	33,607	1,024.5	2.2	374.2	34,431,009	78,323	12,577,146

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 2 (RETURN)

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
CONSTRUCTION ITEMS	990	743.0	8.9	429.9	735,525	8,800	425,636
AIRBORNE SUPPORT EQUIPMENT	8,957	794.8	9.8	355.0	7,118,698	87,286	3,180,024
LESS:	(-1,033)	1051.4	57.2	314.3	-1,086,067	-59,046	-324,650
MMU EXPENDABLES	-80	628.0	0	415.0			
CRYO, H_2	-92	1009.8	-76.0	302.0			
CRYO, O_2	-781	1115.5	78.0	306.0			
N_2, TANK NO. 5	-40	678.0	88.0	330.0			
N_2, TANK NO. 6	-40	1115.0	40.0	287.0			
TOTAL CARGO, DOWN	8,914	759.3	4.2	368.1	6,768,156	37,040	3,281,010

WEIGHT AND BALANCE, ORBITER CARGO—ETVP MISSION NO. 3

ITEM	WEIGHT (LB)	X_o (IN)	Y_o (IN)	Z_o (IN)	ω_x	ω_y	ω_z
PLATFORM ITEMS	(18,800)	1220.0	0	399.0	22,936,000	0	7,501,200
RCS MODULE, INCL. PORT	4,700	1220.0	24.0	446.0			
RCS MODULE, INCL. PORT	4,700	1220.0	-48.0	424.0			
RCS MODULE, INCL. PORT	4,700	1220.0	48.0	374.0			
RCS MODULE, INCL. PORT	4,700	1220.0	-24.0	352.0			
AIRBORNE SUPPORT EQUIPMENT	(7,804)	947.4	- 1.9	375.7	5,868,945	-11,620	2,327,669
BERTHING PLATFORM	1,200	681.9	0	364.0			
FWD PALLET (BERTHING PLATFORM)	575	681.6	0	360.0			
AFT PALLET & MECH (RCS)	2,000	1230.0	0	368.0			
LONG. BRIDGE FTG., STA. 659.9 (2)	172	659.9	0	404.0			
LONG. ATTACH FTG., " (2)	62	659.9	0	410.0			
KEEL BRIDGE FTG., " (1)	59	659.9	0	308.0			
KEEL ATTACH FTG., " (1)	15	659.9	0	404.0			
LONG. BRIDGE FTG., STA. 1159.47 (2)	228	1159.5	0	404.0			
LONG. ATTACH FTG., " (2)	62	1159.5	0	410.0			
KEEL BRIDGE FTG., " (1)	161	1159.5	0	308.0			
KEEL ATTACH FTG., " (1)	15	1159.5	0	308.0			
LONG. BRIDGE FTG., STA. 1281.4 (2)	328	1281.4	0	404.0			
LONG. ATTACH FTG., " (2)	62	1281.4	0	410.0			
DISPLAYS AND CONTROLS	25	556.0	0	451.5			
RMS ADDED END EFFECTOR	100	927.0	-83.0	445.0			
TV CAMERA	20	927.0	-83.0	445.0			
LIGHTS	20	927.0	-83.0	445.0			
CARGO BAY SERVICE PANELS	20	827.0	0	370.0			
ORBITER INTERFACING WIRING	60	942.0	0	370.0			
CHECKOUT SYSTEM	500	730.7	0	414.0			
CRADLE, CHECKOUT EQUIPMENT	150	730.7	0	365.0			
LONGERON BRIDGE FTG., STA. 730.73 (2)	188	730.7	0	404.0			
LONGERON ATTACH FTG., " (2)	62	730.7	0	410.0			
KEEL BRIDGE FTG., " (1)	96	730.7	0	308.0			
KEEL ATTACH FTG., " (1)	15	730.7	0	308.0			
CRYO KIT, H_2 NO. 3	370	1009.8	-76.0	302.0			
CRYO, H_2	92	1009.8	-76.0	302.0			
CRYO KIT, O_2 NO. 3	366	1115.5	78.0	306.0			
CRYO, O_2	781	1115.5	78.0	306.0			
TOTAL CARGO, LESS PAYLOAD	26,604	1152.4	- 0.5	393.2	28,804,945	-11,620	9,828,869
PAYLOAD, INCL. ASE (MAX FOR 250 NMI)	3,396	944.5	0	400.0	4,727,222	0	2,002,000
TOTAL CARGO (UP)	30,000	1117.7	-0.4	394.4	33,532,167	-11,620	11,830,869
LESS: RCS MODULES	-18,800	1220.0	0	399.0	-22,936,000	0	-7,501,200
TOTAL CARGO (RETURN)	11,200	946.1	-1.04	386.6	10,596,167	-11,620	4,329,669